The Thompson River Basin: Pacific Salmon Resources and Environmental Issues

by
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PREFACE

On May 9, 1979 the Federal and Provincial Ministers of the Environment signed an agreement to conduct a review of the water resources of the Thompson River Basin in the form of a Pre-Planning study. The objectives of the review were to describe water quality and quantity, document current and potential water users, outline the associated conflicts and concerns and identify opportunities for improved management. In addition, recommendations for immediate action which could be taken to resolve problems were to be made and programs for future planning outlined.

The Department of Fisheries and Oceans, as part of the above agreement, agreed to prepare a submission on the anadromous salmon resources of the Thompson River Basin. The objective was to describe fish abundance and distribution, summarize the contribution of Thompson River Basin salmon to the commercial, native and recreational salmon harvest and provide an overview of the existing conflicts between land and water uses and fish habitat and water quality. This document details that information and is intended for use by the participants in the study and also the general public. Accordingly, some of the technical information has been simplified in consideration of the expected broad readership.

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ABSTRACT

Knapp, W., M.D. Nassichuk, J. Johnson Turner and I.K. Birtwell. 1982. The Thompson River Basin: Pacific Salmon Resources and Environmental Concerns. Can. MS Rep. Fish. Aquat. Sci. 1668:

Demands for land and water within the Thompson River Basin often conflict with the habitat requirements of Pacific salmon and it is anticipated that the frequency of these conflicts will increase coincident with population and development pressures. In regard to these concerns, a Federal/Provincial Pre-Planning study of the water resources of the Thompson River Basin was implemented and the Department of Fisheries and Oceans prepared a submission outlining water quantity and quality concerns and conflicts related to the anadromous salmon resources.

The report provides an overview of the Basin's salmon resources, including their life histories, spawning and rearing requirements, habitat distribution, escapements, juvenile production and enhancement potential, and summarizes the contribution which these fish make to the British Columbia commercial, recreational and Native Indian harvests. It also describes the conflicts between land and water use activities and salmon habitat and water quality. The discussion is organized according to the three Sub-basins within the study area; the Thompson, North Thompson and South Thompson/Shuswap.

Key Words: Thompson River Basin, Pacific salmon, water quality, fish habitat, water resource conflicts.

RÉSUMÉ

Les terrains et les plans d'eau sont en forte demande à l'intérieur du bassin de la rivière Thompson, phénomène qui entre souvent en conflit avec les exigences écologiques du saumon du Pacifique; on prévoit que ces conflits seront plus fréquents en raison des pressions exercées par la population et le développement. Dans ce contexte, une étude fédérale-provinciale de pré-planification portant sur les ressources aquatiques du bassin de la rivière Thompson a été effectuée et le ministère des Pêches et des Océans a préparé un mémoire sur les problèmes et les conflits liés à la qualité de l'eau et aux ressources en eau qui touchent les stocks de saumons anadromes.

Le rapport donne une idée générale des ressources en saumon du bassin, en traitant notamment du cycle vital des espèces, de la distribution des lieux de fraie et d'élevage et du besoin qu'en ont les espèces, de la remonte, de la production de jeunes, ainsi que du potentiel de mise en valeur, et résume la contribution du bassin aux pêches commerciale, sportive et des autochtones qui se pratiquent en Colombie-Britannique. Le rapport décrit également les conflits qui existent entre, d'une part. l'utilisation que l'on fait de la terre et de l'eau et, d'autre part, l'habitat du saumon et la qualité de l'eau.

La discussion est structurée selon les trois sous-bassins qui composent la région étudiée (Thompson, Thompson-Nord et Shuswap/Thompson-Sud)

Mots-clés: Bassin de la rivière Thompson, saumon du Pacifique, qualité de l'eau, habitat du poisson, conflits liés aux ressources aquatiques.

I
INTRODUCTION

The Thompson River Basin (Figure 1) includes a number of important salmon producing streams and lakes. Continued production of fish in the Thompson River Basin is contingent upon the maintenance of adequate water quality and quantity conditions and the protection of fish habitat. These requirements are becoming increasingly more difficult to maintain as the demands of urban development, forestry, recreation and agriculture continue to encroach upon the salmon's environment.

This report provides a summary of the Basin's salmon resources (Part II) as well as a detailed description of the resources and associated conflicts within the individual drainages (Part III). Part II describes salmon abundance, distribution, enhancement potential, juvenile production, spawning and rearing requirements and utilization by commercial, recreational and Native Indian groups. In Part III, the Thompson River Basin (excluding the Nicola River Basin which is currently being considered under a separate study) has been subdivided into three Sub-basins - the Thompson (Figure 3), North Thompson (Figure 4) and the South Thompson/Shuswap (Figure 5). The latter two Sub-basins are further broken down into a number of distinct regions according to local drainage patterns. The general effects of the land and water use activities prevalent in the Thompson Basin on salmon habitat and water quality are described in Appendix I.

Information for this report was obtained from a variety of sources, including Department of Fisheries and Oceans (DFO) files, technical and manuscript reports, correspondence, available literature and information from other agencies. Printed information was supplemented with information obtained from interviews with regional DFO staff. Spawning escapement data for chinook and coho salmon were derived from DFO spawning catalogues and sockeye and pink data were obtained from the International Pacific Salmon Fisheries Commission (IPSFC) Annual Reports. An earlier draft of this report was utilized in the preparation of a pre-planning report (Canada, DOE and Province of B.C., MOE, 1981).

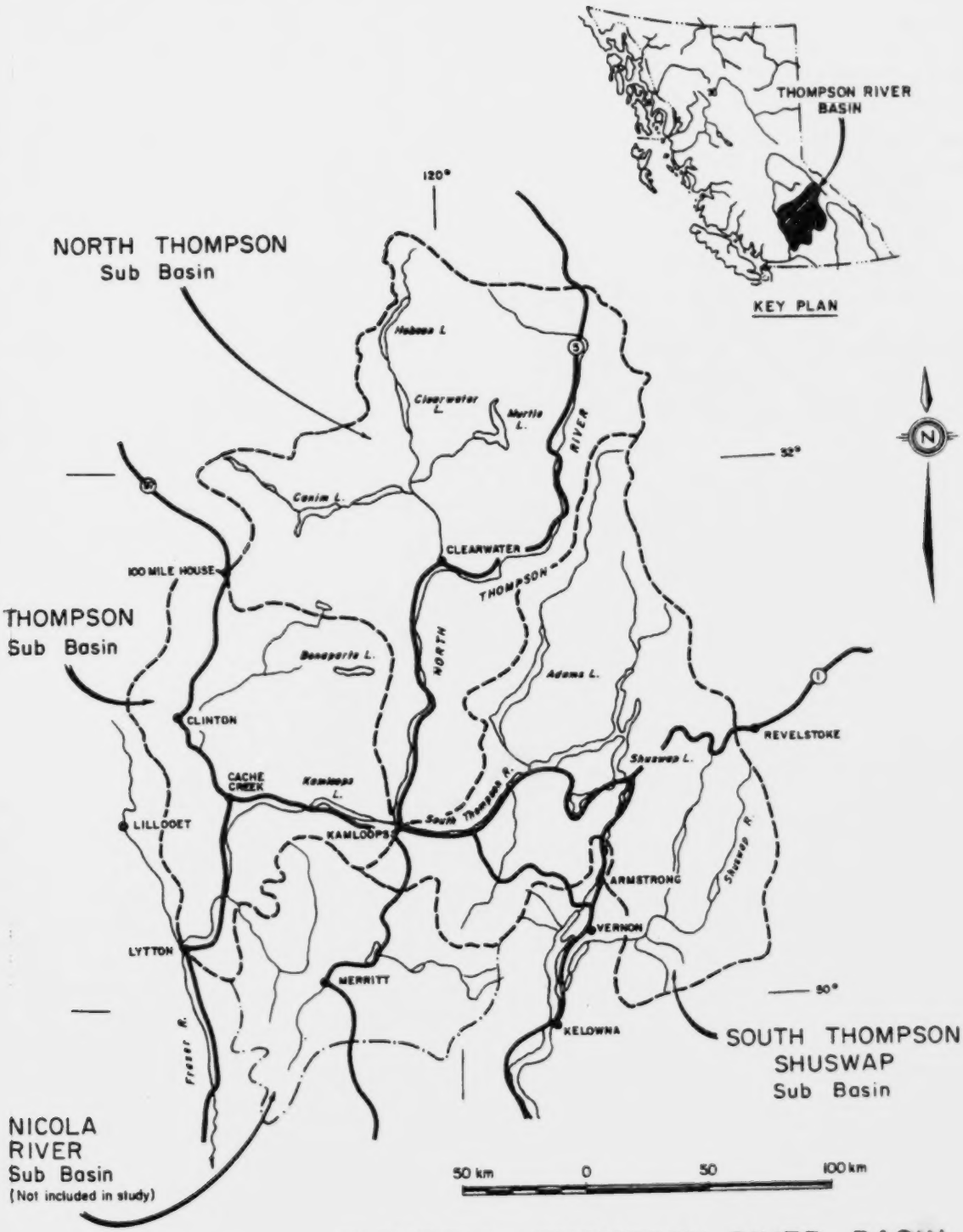

FIGURE I - THOMPSON RIVER BASIN

The present report has been updated to January 1982 to reflect changing management (ie. DFO, IPSFC) priorities and the current status of Thompson Basin land and water use activities. Salmonid enhancement sections are current to December 1981 unless otherwise stated.

The escapement figures for each species have been averaged over the 1969 to 1978 period to yield an "average annual escapement". This value has been rounded off in the text of the report to two significant figures (in-text escapement figures therefore may not absolutely agree with tabulated totals). Updated escapements for 1979 and 1980 are presented in Appendix III.

II
OVERVIEW: THOMPSON RIVER BASIN FISHERY RESOURCES

A. PACIFIC SALMON LIFE CYCLE

Of the five species of Pacific salmon in British Columbia, four are native to the Thompson River system: sockeye (Oncorhynchus nerka), pink (O. gorbuscha), chinook (O. tshawytscha) and coho (O. kisutch). Chum salmon (O. keta) is the only species not present in the study area.

The four species of Pacific salmon which utilize the Thompson River Basin are anadromous. Generally, they emerge from eggs spawned in fresh water, migrate as juveniles to the sea, and upon maturity return to their natal freshwater stream to spawn. Although the life cycles of the salmon are similar, there are essential differences with respect to the timing of migration of the adults and juveniles, and environmental requirements during variable periods of freshwater residence (Figure 2).

Sockeye salmon generally mature in four years, pink salmon in two years, coho salmon in three to four years, and chinook salmon in three to seven years. All adult salmon die soon after spawning.

The difference in life cycles and in survival rates of each race in any year results in a fluctuation in fish abundance from year to year. For example, Thompson River pink salmon escapements are confined entirely to odd-numbered years, while adult migrations of coho, chinook and sockeye occur each year. Sockeye salmon, on the other hand, exhibit a dominant year cyclic pattern which includes large returns every four years. Most streams in the Thompson River system which support sockeye salmon have recorded peak spawning escapements during 1970-74-78 dominant year cycles. In addition to the cyclic escapement patterns, the magnitude of annual escapements depends on the exploitation rates in the commercial, sport and Native food fisheries, and on environmental influences affecting survival in fresh water and marine environments (Canada, Dept. of the Environment (DOE) 1974).

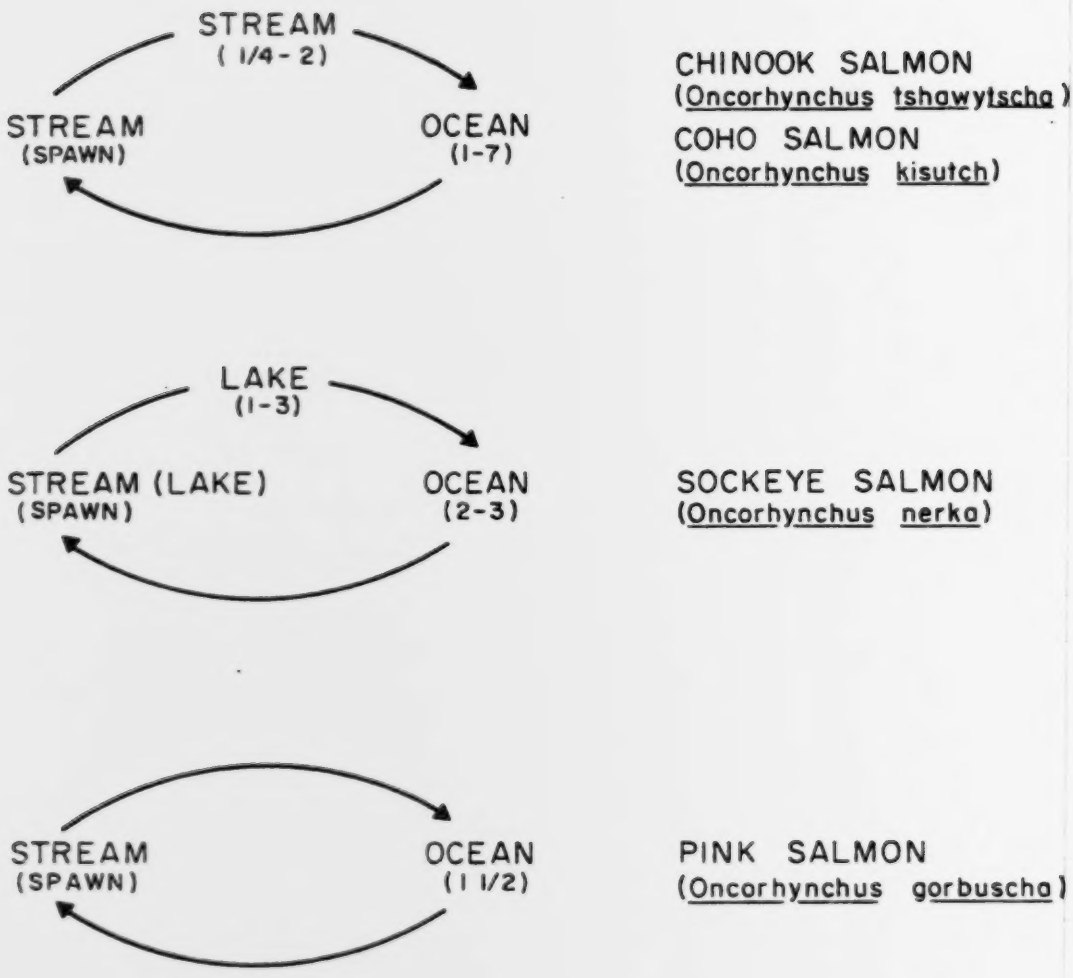

FIGURE 2 - LIFE CYCLES OF THOMPSON RIVER PACIFIC SALMON

(Adapted from Canada, DOE, 1974)

The timing of adult salmon migration and spawning is influenced in part by the temperature and discharge rates of spawning streams. Salmon will migrate upstream when these conditions are optimal for successful spawning. Prior to their passage upstream, adult salmon store energy in the form of convertible protein and fat. Once upstream migration begins, adult salmon generally do not feed and are dependent upon this stored reserve for survival. The quantity stored is generally in direct proportion to the distance the fish must migrate. This food reserve can be depleted prematurely by increased metabolism due to elevated water temperatures or increased exertion imposed by areas of difficult passage or prolonged migration (Canada, DOE, 1974). Increased total metabolic activity reduces the stored energy available for spawning activity and may cause pre-spawning mortality. The resultant reduction in egg deposition could endanger the viability of individual races and entire populations. For example, a nine to twelve day delay is sufficient to prevent Thompson River stocks from reaching their spawning grounds, and even shorter delays may reduce spawning success (Canada, DOE, 1974). Delays during upstream migration necessarily result in later than normal arrival at spawning areas.

In general, salmon migration and spawning in the Thompson River Basin commences as early as mid-summer, reaching a peak in late summer and fall, and concluding in early to mid-winter. Chinook salmon arrive on the spawning grounds from mid-July and spawn from August to October; pink salmon arrive in late September through October and spawn in early October; coho salmon arrive in late August through October and spawn from mid-October through November. Some areas (eg, Eagle River, Scotch Creek, Anstey River) also have an early run of sockeye which arrive on the spawning grounds in August and spawn in late August and September (Brown, Musgrave and Marshall, 1979; IPSFC, Annual Reports, 1969 to 1978).

Salmon deposit their eggs in the gravel of streams and lake beach areas. The eggs develop during the fall and winter months and hatch in the spring. After hatching, the yolk-carrying alevin continue to develop and emerge from the gravel as free-swimming fry from March to June. Typically, sockeye fry then

migrate into a lake where they reside for a year, (two years in rare instances) before migrating to sea the following spring. Pink salmon fry migrate directly to the ocean following emergence from the gravel. Chinook migrate seaward as advanced fry (from mid-April to late July) or remain in streams or lakes for a year or more prior to migration. Coho generally rear in streams and lakes for one year after emergence from the gravel before migrating to the ocean (Hart, 1973; Scott and Crossman, 1973).

B. SPAWNING AND REARING DISTRIBUTION

All four species of salmon native to the Thompson River Basin do not necessarily spawn in either the same stream reaches or the same streams. Chinook salmon, for example, the largest of the Pacific salmon, spawn in three streams of the Thompson Sub-basin, in nine streams of the North Thompson Sub-basin, and in nine streams of the South Thompson/Shuswap Sub-basin (See Appendix II).

Although sockeye salmon do not spawn in the Thompson River Sub-basin, juvenile fish from other Sub-basins rear in Kamloops Lake. Sockeye spawn in four streams of the North Thompson Sub-basin (Appendix IIB) with juveniles rearing for a year in Kamloops and North Barriere Lakes prior to migrating to the sea (IPSFC, Annual Reports, 1969 to 1978). Sockeye salmon spawn in fourteen streams and numerous lake beach areas of the South Thompson/Shuswap Sub-basin; the juveniles rear in nearby lakes.

Pink salmon spawn principally in the mainstem Thompson River from Spences Bridge to Savona, although other small runs spawn in three streams of the South Thompson Sub-basin and in the Deadman and Bonaparte Rivers. An escapement of 150 pink salmon to the North Thompson River in 1977 was the first record of pinks spawning in this Sub-basin (Brown et al , 1979).

Coho salmon spawn and rear in three streams of the Thompson Sub-basin (Appendix IIA), in seventeen streams of the North Thompson Sub-basin (Appendix IIB) and in twenty-two streams of the South Thompson/Shuswap Sub-basin (Appendix I and III).

C. THOMPSON RIVER BASIN ESCAPEMENTS

The Thompson River Basin is a major contributor to the salmon stocks of the Fraser River system, the largest salmon producer in British Columbia. The estimated average (1969-78) annual salmon escapement of sockeye, chinook, coho and pink to the entire Fraser River system was 2.5 million fish (Canada, DFO, 1979). The annual average escapement of these species to the Thompson River Basin is 800,000 spawners, approximately 32% of the Fraser River salmon escapements (Brown et al, 1979). Listed below are the average annual escapements for the four salmon species spawning in the Thompson River Basin (Table II) and the same figure expressed as a percentage of the total escapement of that species to the Fraser River system. (Canada, DFO, 1979).

Sockeye	556,400	42.9%
Chinook	23,700	35.9%
Coho	14,900	23.2%
Pink	204,900	19.3%

Since sockeye salmon exhibit natural cyclic phenomena as noted earlier, ten year average values do not reflect the wide range in escapements recorded for individual years. For example, in the ten year period (1969-78) the average annual escapement of sockeye salmon for dominant years only (1970, '74, '78) is 1.6 million fish while that for the remaining, sub-dominant years is 116,000 spawners. Pink salmon escapements are also highly cyclic, occurring only in odd years in the Thompson River system. For the purposes of this report, ten-year average escapement values are used in comparing populations for different streams and in calculating the annual average contribution of these stocks to the commercial fishery.

D. SPAWNING REQUIREMENTS

Occurrence of salmon spawning is determined by a variety of physical and chemical conditions including temperature, water depth, velocity, stream gradient, channel configuration and gravel size. Similarly, the viability of developing eggs and fry is dependent upon the maintenance of suitable water quality and

physical surroundings. Although a detailed treatment of the variables involved is beyond the scope of this report, the following provides a brief summary of the more important spawning and rearing requirements. Further information can be found in the literature review prepared by Schmidt, Graham and McDonald (1979).

Optimum spawning gravel size ranges from 0.5 to 15 cm in diameter, with the preferred diameter ranging from 2.5 to 10 cm. The redds or nests constructed by female salmon vary in depth from 15 to 45 cm, or deeper in the case of chinook salmon (Canada, DOE, 1974). Available gravel must therefore be of sufficient depth, uncompacted and free of sand and silt. Excessive quantities of sediment in spawning beds may reduce egg and alevin survival by altering dissolved gas exchange in the gravel and impeding alevin migration through the gravel bed to surface waters (Sheridan, 1962).

For the development of salmonid larvae and mature eggs, Davis (1975) recommends a minimum dissolved oxygen concentration of 9.75 mg l^{-1} (level A criteria). This level represents almost ideal oxygen conditions with little deviation from full saturation (98-100% saturation over a range of 0-25^{0}C), and thus assures a high degree of safety for important fishery stocks (Davis, 1975). The oxygen supply in intragravel water may be depleted both by decomposing flora and fauna and the respiration of benthic communities and developing eggs (Wickett, 1954).

Water temperatures are particularly critical to successful spawning and deviations from the "normal range" may cause mortality of spawning fish or eggs. For the maximum survival of incubating salmon eggs, the water temperature at spawning should range between 5.7^{o}C and 13^{o}C (Burrows, 1963). Warm temperatures may delay spawning and cooler temperatures may result in greater egg mortality (Burrows, 1960).

After the 128 cell stage of development is reached, egg incubation temperatures are not as critical but should remain within 1°C to 13°C. This criterion also applies to emergent and rearing fry; however, at cooler water temperatures there is a

reduced development rate and delayed emergence which may lead to greater mortality. The temperature range for maximum productivity in fingerling salmon is 10°C to 15.6°C (Burrows, 1963).

Water depth and velocity requirements for spawning salmon vary between species; typical values are as follows (Chambers, 1956, Hourston and MacKinnon, 1956):

Species	Water Velocity		Water Depth	
	cm s^{-1}	(feet s^{-1})	cm	(feet)
Chinook	24-68	(0.8-2.3)	30-45	(1.0-1.5)
Coho	18-54	(0.6-1.8)	30-38	(1.0-1.3)
Sockeye	53-54	(1.8-1.8)	30-45	(1.0-1.5)
Pink	46-73	(1.5-2.4)	31-48	(1.0-1.6)

Water depth and velocity also determine the success of egg incubation at redd sites. Insufficient depth may expose incubating eggs to drying and freezing conditions during low winter flows. Stream gradient is an important determinant of both surface water velocity and subsurface percolation, which respectively, facilitate removal of metabolic wastes and ensure an adequate dissolved oxygen supply to incubating eggs.

E. REARING REQUIREMENTS

1. Stream Rearing

Juvenile chinook and coho may spend up to two years in streams prior to seaward migration. To support rearing fry, streams must have a sufficient discharge rate, moderate temperature regime, available food source, shelter and adequate water quality throughout the year.

Stream reared juvenile salmonids feed partly on immature aquatic insects which are largely produced in riffle areas. The most productive riffles are composed of large gravel or cobble serviced by clean, sediment-free, cool, well-aerated water.

Shelter for rearing fish may be found within riffles, but usually is associated with deeper pools or stream margins with overhanging banks and vegetation (Kennedy, 1967). Streamside vegetation provides, for example, shelter from predators, water temperature control, shading, nutrients, a source of aquatic insects and maintains the integrity of the streambank by preventing erosion.

Optimal water quality for rearing freshwater fish populations, including salmonids, is characterized by a dissolved oxygen content greater that 7.25 mg l^{-1} (70% saturation), a temperature range of 10°C to 15.5°C and low turbidity (Davis, 1975; Burrow, 1963; European Inland Fisheries Advisory Commission (EIFAC), 1964).

Excessive sedimentation and turbidity in streams may affect rearing salmonids directly by irritating or clogging gill structures or indirectly, by decreasing fish food production via smothering or reduced light penetration (Cordone and Kelley, 1961). This subject will be discussed in detail in Appendix I.

2. Lake Rearing

Sockeye differ from other species of Pacific salmon in that they usually require a lake area in which to rear. Sockeye fry, after emerging from stream or beach spawning areas, rear in nearshore waters until early July before assuming a deep water existence feeding on freshwater plankton. They normally remain in the lake for one year (sometimes two to three years) prior to seaward migration.

Chinook and coho juveniles remain in foreshore areas from April (when they emerge) through mid-August, feeding on benthic and planktonic organisms. Lake residence duration for chinook ranges from three months to one year in contrast to coho which require a minimum of one year (Hart, 1973).

Limnological and biological conditions in lakes affect the behaviour and survival of salmon fry. Abnormal environmental conditions may alter food abundance, reduce growth, induce

premature migration and lower survival rates. Poor growth may prolong lake residence, so that the lake must support older fish in addition to the new arrivals from the spawning areas. Sockeye productivity may decline since fish with longer freshwater residence times have a lower rate of survival (Narver, 1974).

Water temperature determines the location of salmon rearing sites and the rates of primary productivity. Increased temperatures, for instance, increases phytoplankton growth. Conversely, increased water turbidity inhibits light penetration, reducing photosynthetic activity and therefore phytoplankton production. Extreme turbidity may alter fry distribution and the ability of young sockeye to see and capture food organisms. Low concentrations of dissolved oxygen and high levels of dissolved carbon dioxide may limit the penetration and dispersion of fish into lower strata of deep lakes and, in rare cases, may affect the behaviour of young sockeye in the upper strata (Canada, DOE, 1974).

The amount of nitrate, phosphate and silicate available in lakewater (provided essential trace elements are present) directly influences phytoplankton productivity. The latter support lake zooplankton, which in turn are the major food source of rearing sockeye (Narver, 1974).

F. JUVENILE PRODUCTION

Limited data are available on the rearing and overwintering distributions and migratory patterns of juvenile salmon in the Thompson River basin. The following discussion is based mainly on work by Starr (1978) in the Deadman River and Graham and Russell (1979b) in Shuswap Lake.

The annual average downstream migration of juvenile salmon (based on 1969-1978 data) ranges from an estimated 4.8 million (excluding pink salmon, including non-dominant year sockeye migrants) to 186.8 million fish (including pink and dominant year sockeye salmon migrations) (Table I). All pink and some chinook juvenile migrants are less than one year of age (0+) whereas most sockeye, coho and chinook juvenile migrants are older (1+, 2+), having reared in freshwater lakes and streams.

1. Chinook

Following spring emergence from the gravel, some chinook fry migrate directly to the sea, while others may remain in freshwater for a year or more (Scott and Crossman, 1973). Tagging experiments conducted by Graham and Russell (1979b) have suggested that at least some chinook salmon overwinter in Shuswap Lake or its tributaries. Chinook salmon fry in the Shuswap Lake system appear to remain briefly near their spawning streams before migrating out of Shuswap Lake (Graham and Russell, 1979b).

Studies conducted on the Deadman River from July to October 1977 have revealed that out-migration of chinook pre-smolts (0+) occurs as early as late July (Starr, 1978). Age determinations have shown that 98% of Deadman River chinook spawners overwintered as juveniles in freshwater. Of this overwintering population, 67 to 85% presumably remain in the Deadman River and migrate out to the salt water as 1+ juveniles during the following year's spring freshet. The remaining 15 to 33% migrating out of the Deadman system likely stay in the mainstem Thompson or Fraser Rivers or fail to survive (Starr, 1978).

2. Coho

Deadman River fish migration studies revealed fewer yearling coho salmon in downstream traps compared to chinook salmon and rainbow trout suggesting that coho moved locally within the stream rather than migrating out like chinook salmon and rainbow trout (Starr, 1978). Juvenile progeny of lower Thompson River mainstem coho probably remain near the spawning areas for one year prior to downstream migration.

Downstream coho migration estimates (Canada, DFO, 1981b) and average escapements for the 1969 to 1978 period suggest that an annual average of approximately 224,000 yearling (1+) juveniles migrate through the Thompson River to the sea (Table I). The coho and chinook spring smolts likely migrate between April 1 and May 31, peaking between April 15-30 (Starr, pers. comm.).

TABLE I THOMPSON RIVER BASIN SALMON ESCAPEMENTS AND JUVENILE PRODUCTION

	THOMPSON SUB BASIN		NORTH THOMPSON SUB-BASIN		SOUTH THOMPSON/SHUSWAP SUB BASIN		TOTAL	
	ESCAPEMENT	JUVENILES	ESCAPEMENT	JUVENILES	ESCAPEMENT	JUVENILES	ESCAPEMENT	JUVENILES
Chinook								
Average	2600	19000(0+) 73000(1+)	4600	381000(0+) 45000(1+)	16500	$2.0X10^6$(0+) 20000 (1+)	27200	$24X10^6$(0+) 138000(1+)
Maximum	4300	32000(0+) 121000(1+)	7400	614000(0+) 73000(1+)	25700	$3.1X10^6$(0+) 31000 (1+)	37400	$37X10^6$(0+) 225000(1+)
Coho								
Average	300	4500	9100	137000	5500	82500	14900	224000
Maximum	325	4900	11400	171000	7900	119000	19600	294900
Pink								
Average 1969/71/73/75/77	408500	$5.3X10^7$	150	19500	450	58500	409100	$5.3X10^7$
Maximum	970100	$1.78X10^8$			4100	533000	974200	$1.7X10^8$
Sockeye								
Average	-	-	5900	$4.96X10^5$	550500	$4.62X10^7$	556400	$4.67X10^7$
Maximum	-	-	13600	$1.14X10^6$	1966500	$1.64X10^8$	1980100	$1.65X10^8$
Cycle Averages								
1969/73/77	-	-	3675	$3.10X10^5$	74700	$6.24X10^6$	78375	$6.55X10^6$
1970/74/78	-	-	3550	$2.97X10^5$	1580000	$1.33X10^8$	1583550	$1.33X10^8$
1971/75	-	-	4950	$4.16X10^5$	257475	$2.16X10^7$	262425	$2.2X10^7$
1972/76	-	-	13500	$1.13X10^6$	12075	$1.01X10^6$	25575	$2.14X10^6$

Figures for the Nicola River Sub-Basin are not included (average annual escapements, 1969 to 1978 are 2100 coho, 3800 chinook and 750 pink). Averages have been rounded off and cover the 1969 to 1978 period unless otherwise indicated. Juvenile production estimates are based on SEP design criteria for average percent survival (Canada, DFO, SEP, 1981). The North Thompson pink escapement is for 1977. 835 pinks were recorded in 1979.

3. Pink

Pink salmon migrate seaward immediately following emergence from the gravel in spring (Hart, 1973; Scott and Crossman, 1973). An estimated 78,000 juvenile pinks are produced annually by the 600 adults which spawn in the Thompson River system above Kamloops. In contrast, the average peak year escapement of 408,500 pinks in the lower Thompson (including the small Deadman and Bonaparte runs) yields an annual average downstream migration of 53 million underyearling (0+) fry. The latter figure is based on the 13% egg to fry survival rate used by the Salmonid Enhancement Program (SEP) (Canada, DFO, 1981b). If the 1982 pink escapement exceeds one million as expected, a corresponding increase in juvenile migrants should be realized.

The above calculations may, in addition, underestimate the numbers of juveniles produced from the Thompson River area as evidenced by results of field studies in 1974 (Servizi, 1976):

> "Pink salmon escapement to the Thompson River in 1973 was 281,146 and 63%were calculated to have spawned in the area between Kamloops Lake and Walhachin Bridge, 9 miles downstream. Spawning success of females was 99% and at an average of 1,803 eggs per female, the calculated egg depositions were typical for the Thompson River.
>
> In order to measure egg to fry survival, the total fry migration from the area between Walhachin Bridge and Kamloops Lake was calculated based upon catches using inclined plane samplers. Calculated fry emergence was 44,269,000 giving an egg to fry survival of 27%. This value is considerably higher than average for egg to fry survival for natural spawning grounds in the Fraser River system as a whole. Comparable measurements have not been made previously in the Thompson River, but with such a high survival rate indicated for 1973-74, a reduction from earlier years seems improbable. The number of pink salmon spawners in the Thompson River and its tributary increased from 283,000 in 1973 to approximately 450,000 in 1975, even though the total run of pink salmon to the Fraser River system was less in 1975 than in 1973".

4. Sockeye

Although no sockeye spawn within the Thompson River, some North Thompson Sub-basin sockeye fry from the Raft and North Thompson Rivers are believed to rear in Kamloops Lake. Furthermore, large numbers of North Thompson and South Thompson/Shuswap sockeye smolts (1+) utilize the lower Thompson River as a migration route. For example, between 1969 and 1978, an estimated 130 million sockeye smolts (mainly 1+), progeny of peak year sockeye salmon spawners (i.e. the 1970 cycle year), migrated down the Thompson River.

G. SALMONID ENHANCEMENT

The Salmonid Enhancement Program (SEP), initiated in 1977, is designed to create significant economic, social and resource benefits through the increased production of Canada's Pacific salmonid resource. The long term goal of the program is to increase salmonid production by up to 190 million pounds per year while contributing to the national income, regional development, employment, Indian well-being and environmental preservation goals of government (Canada, DOE and Prov. of B.C., 1977 to 1979).

The objective of Phase I, of seven years duration, is to increase the salmonid supply by about 50 million pounds per year through application of a judicious mix of low, intermediate and high technology (eg. stream improvement, incubation boxes and hatcheries).

Phase II will have variable annual salmon production targets based on the attainment of the Federal and Provincial governments' current economic and social benefits (Canada, DOE and Province of B.C., 1978). The long term management and SEP objectives for the Thompson River system are focused primarily on chinook and coho salmon and steelhead trout. Various hatchery opportunities, the feasibility of which is currently being evaluated, have been identified for the Thompson River system. Systems being studied include the Mahood, Barriere, Salmon,

Eagle, Lower Shuswap, Middle Shuswap and the South Thompson Rivers (Kahl, Whyte and Fee, 1978; Steele, pers. comm.).

A coded-wire tagging program for chinook and coho has been conducted within several Thompson River Basin streams since 1976. Tagging of juvenile chinook from stocks of the Deadman, Thompson, Lower Shuswap and Middle Shuswap Rivers was undertaken in order to study the migratory and rearing habits of the fish, and to determine the feasibility of enhancing these stocks (Buxton, 1980).

In 1978, the Provincial Fish and Wildlife Branch, in an effort to identify potential enhancement sites, initiated a radio-tagging program of steelhead to study overwintering and spawning habits. The study area ranged from Lytton to Savona, and encompassed the Deadman, Nicola and Bonaparte Rivers (Canada, DOE and Prov. of B.C., 1977 to 1979).

Fraser River management biologists in conjunction with SEP biologists are currently preparing a management strategy for the entire Fraser River in which further proposals for stock enhancement in the Thompson River system play a major role. In addition, the IPSFC, which is responsible for managing Fraser River sockeye and pink salmon stocks, has recognized the potential for enhancement of these species (IPSFC, 1972). Specific information on identified SEP and IPSFC enhancement opportunities will be included in individual Thompson River Sub-basin discussions.

H. FISHERY RESOURCE UTILIZATION

Although no commercial harvest occurs within the Thompson River Basin, indigenous stocks contribute substantially to the Canadian and American commercial fisheries, the freshwater and tidal sport fishery and both Thompson and Fraser River Native Indian food fisheries. The "net wholesale values" of Thompson Basin stocks landed in these fisheries were computed from catch to escapement ratios derived from Tables II, III, IV, and V. In addition, certain nonconsumptive recreational and cultural benefits are derived from this resource.

1. Commercial Fisheries

Although a commercial salmon harvest does not occur within the Thompson River Basin, the region's stocks do contribute substantially to commercial landings downstream. The estimated annual Canadian commercial catch of salmon and net wholesale values ($1978) associated with salmon stocks of the Thompson River system are as follows:

Species	Estimated Annual Catch	Net Wholesale $ Value
Sockeye	1,290,750	11,268,247
Chinook	83,421	1,091,980
Pink	372,570	1,438,121
Coho	19,267	188,622
	1,766,008	13,986,970

The total estimated annual net wholesale value for the entire system was approximately $14 million. The Thompson, North Thompson, and the South Thompson/Shuswap Sub-basins contributed $1.6 million (11.4%), $446,000 (3.2%), and $12 million (85.4%), respectively, to this total value (Table II; Masse and Peterson, 1977).

In addition to providing a substantial base for the B.C. commercial salmon fishery, Thompson River stocks also contribute approximately 1.1 million salmon (79% sockeye and 19% pink) annually to the American commercial fishery, equivalent to roughly $8.7 million (Canadian). None of the proceeds from these intercepted fish are recoverable in Canada however.

During recent Canada-United States salmon negotiations, a plan was outlined under which both countries would be required to reduce proportionally those fisheries experiencing conservation problems. Formulas for an interception limitation scheme for Fraser River sockeye and pink salmon caught in the American fishery were also proposed (Jones, pers. comm.).

TABLE II THOMPSON RIVER SYSTEM* FISHERY RESOURCE UTILIZATION

Region	Species	Escapement 1969-78 Avg. (6)	Commercial Fishery Canadian # Fish (1)	Canadian $ 1978 (1)	American # Fish (1)	American $ 1978 (5)	Sport Fishery ** (Tidal) # Fish(2)	(Tidal) $ 1978(3)	Native Food Fishery # Fish(4)	Native Food Fishery $1978(4)
Thompson Sub-Basin	Chinook	2,599	9,148	119,747	1,663	21,769	8,317	175,332	366	4,791
	Coho	265	342	3,348	175	1,713	254	5,354	191	1,870
	Pink	204,270	371,487	1,433,940	280,032	772,123	--	--	437	1,686
									6,160[7]	53,777[7]
	Total	207,134	380,977	1,557,035	281,870	795,605	8,571	180,686	7,154	62,124
North Thompson Sub-Basin	Chinook	4,575	16,104	210,801	2,927	38,315	14,640	308,612	6	78
	Coho	9,132	11,780	115,326	6,027	59,005	8,767	184,809	27	264
	Sockeye	5,865	13,607	118,789	9,149	79,870	--	--	--	--
	Pink	150	273	1,054	147	567	--	--	67	259
	Total	19,722	41,764	445,970	18,250	177,757	23,407	493,421	100	601
South Thompson Shuswap Sub-Basin	Chinook	16,525	58,169	761,432	10,575	138,426	52,880	1,114,710	147	1,924
	Coho	5,538	7,145	69,948	3,456	35,792	5,316	112,062	8	78
	Sockeye	550,493	1,277,143	11,149,458	858,770	7,497,062	--	--	471	4,112
	Pink	445	810	3,127	436	1,683	--	--	--	--
	Total	573,001	1,343,267	11,983,965	873,437	7,672,963	58,196	1,226,772	626	6,114
Thompson River System Total *		799,857	1,766,008	13,986,970	1,093,557	8,646,325	90,174	1,900,879	7,880	68,839

(1) Catch to Escapement Ratios used are: Chinook 8:1; Sockeye 4:1; Coho 3:1; Pink 2.8:1. Commercial catch (net wholesale value) is calculated from these ratios (Masse and Peterson, 1977).

(2) Barclay (1977).

(3) Based on an average of 2.7 anglers per boat and a value of $17.35 per angler day.

(4) (Bennett, 1973). These figures indicate where fish were taken, but do not indicate the origin of the fish. They are valued at commercial prices (Masse and Peterson, 1977).

(5) This is the estimated net wholesale value of these salmon if caught in the Canadian fishery. However, Canada presently receives no monetary benefits for these fish.

(6) (Masse and Peterson, 1977). The 10 year average escapement does not reflect peak spawning populations due to cyclic and dominant year patterns found in the pink and sockeye salmon life cycle.

(7) Represents the number of sockeye salmon taken by the Native food fishery.

* Information regarding salmon from the Nicola River Basin is not presented in this report.
** Freshwater Sport Fishery contributes $79,629.

2. Tidal and Freshwater Sport Fishery

Thompson River stocks contribute both to the tidal sports fishery within Georgia Strait, as well as the freshwater sport fishery which occurs at various locations within the Thompson River Basin and along the Fraser River below the Thompson River confluence.

The estimated contribution of the Thompson River system to the Georgia Strait tidal sport fishery is valued at approximately $1.9 million ($1978) annually (Table II; Masse and Peterson, 1977; Barclay, 1977). This value is a measure of consumer surplus, or the amount of satisfaction expressed in dollars, that consumers experience from the consumption of a particular commodity (in this case recreation).

The Thompson River Basin sport fishing activity is centered at the Thompson rapids in the Thompson Sub-basin, in the mainstem North Thompson downstream of Barriere (following a 1978 upstream closure) and in Shuswap Lake and River (except for some closed areas) in the South Thompson/Shuswap Sub-basin. Thompson Basin stocks are open to downstream interception in the Fraser River sport fishery (Masse and Peterson, 1977; Barclay, 1977). Approximately 4900 angler days of the lower Fraser bar fishery are attributable to the Thompson Basin stocks.

3. Native Food Fisheries

The Thompson River salmon are of vital importance to the Native people, both economically (as a food source) and culturally (as a focus for their activities). Native people land an estimated 16,000 to 17,000 sockeye and 300 to 400 chinook annually within the Thompson River Basin, primarily as a result of catches in the Thompson Sub-basin, the lower Shuswap River and parts of the upper North Thompson River. These figures do not include salmon originating in the Thompson River which may be intercepted by other native groups fishing in the Fraser River.

A methodology which places a total dollar value on the Native food fishery has not yet been devised. However, insight

into the fishery's cultural importance may be gained from a report by Bennett (1973).

> "Fish play a big role in the life style of the Fraser River Indians. Fishing forms a part of all major facets of their lives; family and social activity, recreation, economics, sustenance, tradition...Fishing is a link with the past; an integral portion of their way of life as it was for the people before them."

4. Recreational Benefit

The salmon resources of the Thompson River also contribute to outdoor recreational enjoyment. For example, the lower Adams River was established as a park and reserve for protection of the unique salmon resources of the area, and has resulted in thousands of people visiting the Salmon Arm area annually (Brown et al, 1979; Canada, DFO 1974-78).

III
SUB-BASIN RESOURCES AND ENVIRONMENTAL ISSUES

A. THOMPSON RIVER SUB-BASIN

1. Introduction

The southern Thompson River between Kamloops and Lytton along with its tributaries, the Deadman and Bonaparte Rivers (Figure 3), are the only known salmon-supporting watercourses in this Sub-basin (salmon passing through the mainstem Thompson River bound for the Nicola River are not discussed in this report). Most coho, chinook and pink salmon spawning occurs in the mainstem Thompson River. The Sub-basin also supports large populations of salmon moving to or from upstream areas. Salmon enhancement projects have been proposed to increase the utilization of potential salmon-bearing streams.

Within the Thompson River Sub-basin, the major sources of conflict between the salmon resources and land and water use are located in or near the City of Kamloops. Of particular concern are the effluent discharges originating from the City of Kamloops and the Weyerhaeuser pulpmill.

2. Fishery Resources

(a) Escapements

The average annual escapement of Pacific salmon to the Thompson River Sub-basin for the 1969 to 1978 period is 260 coho, 2600 chinook and 204,000 pinks (Appendix IIA). The Thompson River mainstem contributes, 75%, 94% and 99.9%, respectively, of the above escapement totals. Although pink salmon in the Thompson River spawn only in odd-numbered years, pink escapements have been calculated on an annual basis. Pinks spawn in scattered areas along the mainstem Thompson River, principally between Spences Bridge and Savona. Although sockeye do not actually spawn in the Sub-basin, many progeny of North Thompson Sub-basin sockeye rear in Kamloops Lake for up to one year prior to seaward migration. In addition, all migrating adult and juvenile salmon utilizing the North or South Thompson/Shuswap Sub-basins must pass through the Thompson River and Kamloops lake.

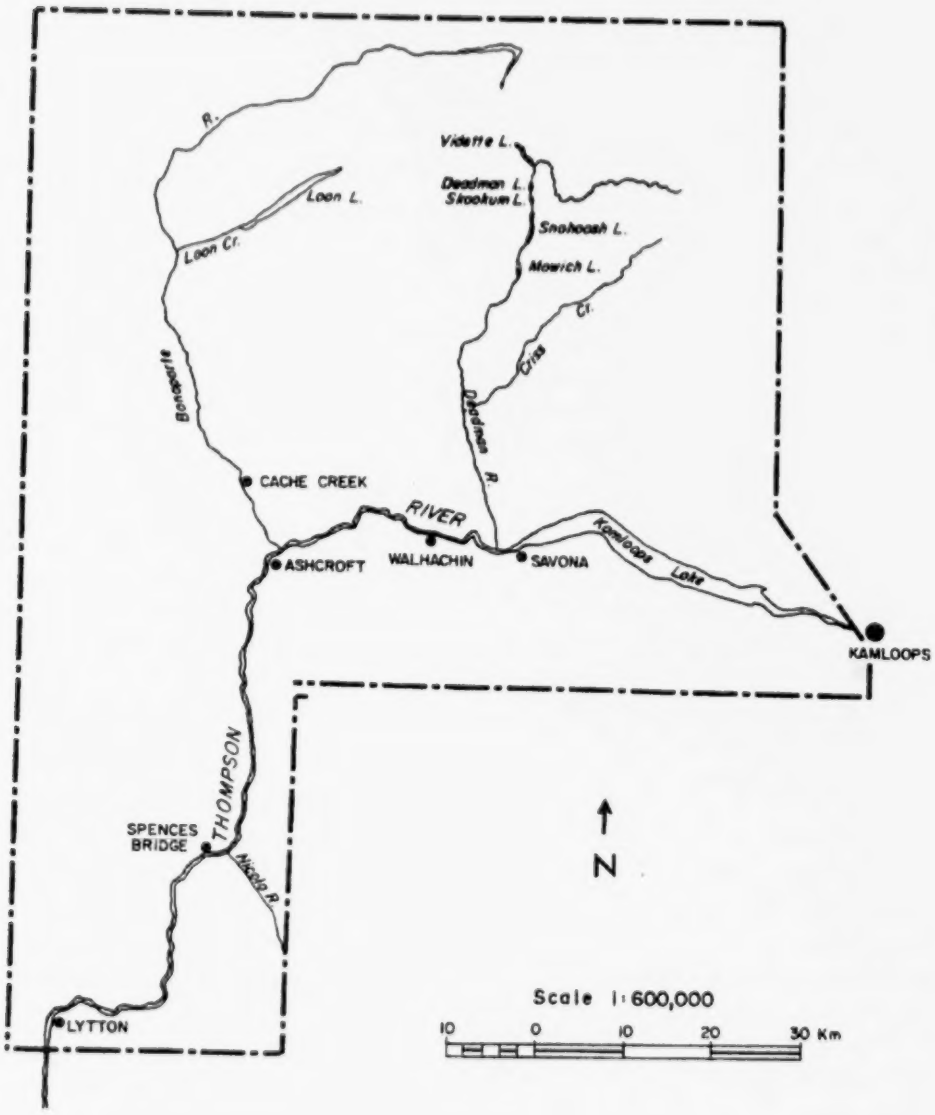

FIG. 3 THOMPSON SUB-BASIN.

The only other known spawning sites within the Sub-basin are situated in the Bonaparte and Deadman Rivers. Small annual escapements of coho and chinook salmon (less than 50 each) and pink salmon (200) have been recorded in the Bonaparte River. Spawning occurs from the mouth of the river to a point 3.2 km upstream, where the combination of an unused dam (originally constructed by B.C. Electric) and waterfall forms an impassable obstruction. Spawning did occur occasionally in the upper reaches of the river prior to dam construction (Meyer, pers. comm.). Records indicate that up to 400 chinook and 3500 coho salmon utilized the Bonaparte River for spawning during the 1950's (Brown et al., 1979).

The Deadman River supports small runs of coho, chinook and pink salmon (50 to 100 of each species). While chinook and coho spawn throughout, pink salmon utilize only the lower 0.8 km of the river. Numerous natural (e.g. beaver dams) and man-made obstructions (e.g. irrigation dams) limit fish access throughout the river. Early 1950's spawning records for the Deadman River indicate maximum runs of 3500 chinook and 3500 coho.

(b) Fishery Resource Utilization

Although salmon are not harvested commercially within the Sub-basin, indigenous stocks contribute an estimated net wholesale value ($1978) of approximately $1.6 million to the Canadian commercial fishery. American commercial catches originating from the Sub-basin are valued at an additional $796,000, while the Georgia Strait tidal sports fishery is valued at $181,000 (Table III; Canada, Dept. of Fisheries and Oceans (DFO) 1974-1978). Of the estimated 1000 chinook salmon taken annually in the Thompson River sports fishery, approximately 100 originate from the Thompson Sub-basin (Canada, DFO, 1974-1978). Although the greater portion of Native food fishery landings within the Thompson Sub-basin are composed mainly of migrating adult sockeye from other Sub-basins (14,000 sockeye were taken between Lytton and Savona in 1978). Sub-basin stocks contribute an annual average of 440 fish.

TABLE III THOMPSON SUB-BASIN RESOURCE UTILIZATION

Thompson Sub-Basin	Species	Escapement 1969-78 Avg. (6)	Commercial Fishery: Canadian # Fish (1)	Commercial Fishery: Canadian Net Wholesale $1978 (1)	Commercial Fishery: American # Fish (1)	Commercial Fishery: American Net Wholesale $1978 (5)	Sport Fishery: Tidal # Fish (2)	Sport Fishery: Tidal $ 1978 (3)	Native Food Fishery # Fish (4)	Native Food Fishery $ 1978 (4)	Total Value $ 1978
	Chinook	2,599	9,148	119,747	1,663	21,769	8,317	175,332	366	4,791	321,639
	Coho	265	342	3,348	175	1,713	254	5,354	191	1,870	12,285
	Pink	204,270	371,487	1,433,940	200,032	772,123	--	--	437	1,686	2,207,749
									6,160[7]	53,777[7]	53,777[7]
Sub-Basin Total	All Species	207,134	380,977	1,557,035	201,870	795,605	8,571	180,686	7,154	62,124	2,595,450

(1) Catch to Escapement Ratios used are: Chinook 8:1; Sockeye 4:1; Coho 3:1; Pink 2.8:1. Commercial catch (net wholesale value) is calculated from these ratios (Masse and Peterson, 1977).

(2) Barclay (1977).

(3) Based on an average of 2.7 anglers per boat and a value of $17.35 per angler day.

(4) (Bennett, 1973). These figures indicate where fish were taken, but do not indicate the origin of the fish. They are valued at commercial prices (Masse and Peterson, 1977).

(5) This is the estimated net wholesale value of these salmon if caught in the Canadian fishery. However, Canada presently receives no monetary benefits for these fish.

(6) (Masse and Peterson, 1977). The 10 year average escapement does not reflect peak spawning populations due to cyclic and dominant year patterns found in the pink and sockeye salmon life cycle.

(7) Represents the number of sockeye salmon taken by the Native food fishery.

(c) Salmonid Enhancement

The provincial government has operated a hatchery at the confluence of Loon Creek and the Bonaparte River since the early 1950s. Until 1979, the hatchery acted as a seasonal (spring and fall) redistribution center for rainbow and brook trout stocks. In 1979, the facility was expanded and renovated to accommodate year-round enhancement of chinook and steelhead (Canada, DFO and Prov. of B.C. 1979; Sparrow, pers. comm.).

A hatchery at Savona, now being considered, could be a major producer of chinook, coho, and pink salmon and steelhead trout. At present, an impassable falls and unused dam restrict salmon migration and spawning to the lower 3.2 km of the Bonaparte River and exclude approximately 100 km of potential juvenile salmon rearing habitat from production. Removal of the dam or installation of a fishway is under consideration (Meyer, pers. comm.) and results of steelhead and chinook fry stocking experiments presently being attempted above the falls appear promising. From 1977 to 1979, water quality and temperature studies were undertaken by DFO but were discontinued when water supply, groundwater quality and land access problems arose (Shepherd, pers. comm.). There may be potential for side channel development for pinks in the mainstem Thompson River (Steele, pers. comm.).

3. Environmental Issues

(a) Agriculture

The major agricultural activities of this Sub-basin are ranching and the cultivation of forage crops. The impacts resulting from these activities are most evident on the Deadman and Bonaparte Rivers, which exhibit lower flows than the mainstem Thompson River.

Among the agriculture-related impacts observed on the Deadman and Bonaparte Rivers are aggravation of the extremely low natural flows of early spring and late summer/early fall, by withdrawal of water for irrigation. In addition bank destruction,nutrient enrichment, reduced streambank integrity,

and increased erosion and water temperatures can result from land clearing activities. Debris accumulation resulting from agricultural activity may restrict fish migration and alter riverbed characteristics. Clearing of the debris has been carried out by local DFO personnel and ranchers.

A management policy is now being developed for the Deadman River by DFO, B.C. Forest Service, Provincial Water Management Branch and the local ranching community. A major concern of this working group is the channelization and riverbed alteration resulting from the use of dams to control high flows during freshet (Meyer, pers. comm.). Following 1974-1975 studies of the water requirements for Deadman River fishery resources, an agreement to release water from Snohoosh Lake during low flows was prepared to satisfy both fishery and agricultural flow needs (Hamilton, 1974).

On the mainstem Thompson River at Walachin, a proposed cattle feedlot has caused some concern due to the potential for aquatic impacts during both construction and operation.

(b) Urban Development

(i) Kamloops Sewage

The City of Kamloops discharges dechlorinated, lagoon-treated sewage into the Thompson River at Kamloops. Following studies of Thompson River periphyton, macroinvertebrate communities and water chemistry (Langer and Nassichuk, 1975; Servizi, 1976) Kamloops Lake limnology (St. John et al., 1976) and nutrients (Oguss and Erlebach, 1975), the Thompson River Task Force (1975) recommended a significant reduction in the discharge of phosphorus from the City of Kamloops and the Weyerhaeuser Canada Ltd. pulpmill (Canada, DOE and B.C. DOE, 1976). As a result, the City, under Provincial Waste Management Branch direction, has instituted a variable drawdown scheme whereby sewage effluent is stored in the lagoons during times of low river flow, treated with alum to reduce phosphate levels and then discharged to the Thompson River during periods of high river flow (spring and fall). The drawdown scheme is considered by DFO to be an interim solution to the sewage disposal problem at Kamloops (Canada, DFO, Unpublished files).

A joint Inland Waters Directorate/Weyerhaeuser Canada Ltd. study conducted over the winters of 1980 and 1981 examined algal growth rates and phosphorous nutrition above and below the point source discharges immediately above Kamloops Lake (ie. the City of Kamloops sewage discharge and Weyerhaeuser pulp mill). The study confirmed that algal accumulations in the lower Thompson River were due to the elevated phosphorus levels produced by the preceding point discharges (Bothwell and Daley, 1981).

In response to the forecasted population growth for the City of Kamloops, an increase in effluent discharged to the Thompson River was proposed in early 1981. This application was subsequently denied and in April, 1981 the B.C. Government formed the Kamloops Waste Management Task Force to explore the technical and financial options available for treatment and disposal of the effluents being discharged by the City of Kamloops and Weyerhauser Canada to the Thompson River. DFO input regarding fisheries concerns was requested and a submission forwarded to the Task Force in October, 1981.

(ii) Ashcroft Sewage

In 1975, the Village of Ashcroft proposed the introduction of secondary sewage treatment and a doubling of its sewage discharge to the Thompson River to 750,000 IGPD (Imperial gallons per day). The DFO, Environmental Protection Service (EPS) and the B.C. Fish and Wildlife Branch objected to the proposal because of the absence of a requirement for nutrient removal. Despite these objections, a Pollution Control Branch (now the Waste Management Branch) permit was issued without a phosphate removal requirement (Canada, DFO, Unpublished files).

(c) Minimum Flows

The Deadman River is subject to low flows as a result of natural conditions and agricultural water withdrawals. In order to resolve some of the problems stemming from these withdrawals, DFO recommended in 1974 that restrictions be placed on water withdrawals during periods critical to the survival of salmon, that proper intake screens be installed and that all unauthorized

dams and obstructions be removed from the river (Hamilton, 1974). Recently, 6.2 x 10^6 m^3 of water storage have been developed at Snohoosh Lake with the aid of Agricultural and Rural Development Subsidiary Agreement (ARDSA) funding. The reservoir is managed by the Deadman River Improvement District which has allocated 2.5 x 10^6 m^3 to augment low flows for fisheries. The remaining 3.7 x 10^6 m^3 of stored water are for irrigation. A water use agreement between DFO and the Comptroller of Water Rights is to be signed in the near future (Hamilton, pers. comm.).

Naturally occuring low flows on the Bonaparte River coupled with irrigation withdrawals lead to restricted flows and high water temperatures which have caused prespawning and rearing mortalities of salmon (Brown et al, 1979). A clause for the protection of fishery resources is being inserted in newly issued and renewed water licences.

The natural falls and power dam 3.2 km upstream of the Bonaparte River mouth (the latter originally constructed by the B.C. Electric Company for Ashcroft power) effectively eliminate upstream migration. Prior to the construction of the dam, migrants were able to negotiate the falls during periods of adequate flow (Meyer, pers. comm).

Water licences for the Bonaparte River are almost fully committed. New withdrawal licences are restricted to the freshet period unless facilities are provided for the diversion and storage of water during periods of high flow. Minimum flow requirements for salmon spawning, rearing and incubation in the Bonaparte River system are undetermined.

(d) Forest Harvesting and Wood Conversion

The only pulpmill within the Thompson Sub-basin is operated at Kamloops by Weyerhaeuser of Canada Ltd. The bleached kraft mill discharges treated effluent to the Thompson River. The pulpmill's contribution to water quality degradation has been reviewed in a report by the Thompson River Task Force (Canada, DOE and B.C. DOE, 1976). Recommendations in the report specific to the pulpmill discharge were as follows:

1. The discharge of phosphorus from the Weyerhaeuser Canada Ltd. pulpmill should be significantly reduced.

2. Colour in the Weyerhaeuser Canada Ltd. pulpmill effluent should be reduced to achieve public and aesthetic acceptance.

3. Studies should be initiated to identify and remove fish tainting agents from the major point source discharges (Weyerhaeuser Canada Ltd. and City of Kamloops) to the Thompson River System.

Several potential research topics were also suggested, including the isolation and characterization of effluent constituents toxic to Kamloops Lake or Lower Thompson River biota and investigation of the effect of altered algal and invertebrate community structures on salmonid feeding ecology.

In response to the Task Force report, Weyerhaeuser Canada Ltd. is continuing to develop colour removal techniques and has carried out an examination of the phosphorus balance within the mill. Under the terms of their effluent discharge permit, the company is continuing a monitoring program of selected physical and chemical parameters and benthic invertebrates in the North and South Thompson Rivers adjacent to Kamloops and in the Thompson at Savona and Walhachin (Canada, DFO, Unpublished files). The Kamloops Waste Management Branch has carried out a similar monitoring program in the North and South Thompson Rivers.

Commencing July, 1979, the Inland Waters Directorate entered into an agreement with Weyerhaeuser Canada Ltd. to conduct a joint research project to determine whether benthic algal growth rates and phosphorus nutrition were higher in the Thompson at Savona than in the upper Thompson, and more specifically whether the point source additions of phosphorus above Kamloops Lake (Weyerhaeuser and the City of Kamloops) were responsible for algae accumulations below the lake. The studies revealed significantly higher phosphorus concentrations in the lower Thompson River than in the North or South Thompson over the winters of 1980 and 1981. Furthermore, higher benthic algal growth rates were observed below Kamloops Lake than above. It

was concluded that the nuisance algal growths in the lower Thompson were due to the phosphorus inputs from the Weyerhaeuser mill and the City of Kamloops sewage discharge (Bothwell and Daley, 1981).

Recent static bioassay data indicates that effluent from the Weyerhaeuser mill is not acutely toxic to rainbow trout (96 hr LC50 = 100%); however, the potential sub-lethal effects of the effluent on fish populations are unknown. Over the past few years spills of process chemicals (eg. black liquor) from the Weyerhaeuser mill have occurred (Canada, DOE, Unpublished files). If such spills bypass the effluent treatment system, toxic chemicals could reach the Thompson River. Exfiltration of effluent from treatment ponds to the Thompson River has also occurred (Canada, DFO, Unpublished files).

In addition to implementing the Thompson River Task Force recommendations and the routine monitoring required under permit, the mill is required to undertake effluent treatment modifications and ensure that neither the water quality nor the biological integrity of the Thompson River are impaired due to the discharge.

The Kamloops Waste Management Task Force formed in April 1981 by the B.C. Government is exploring the technical and financial alternatives for treatment and disposal of the effluents being discharged by Weyerhauser Canada and the City of Kamloops to the Thompson River. The Task Force requested DFO input regarding fisheries concerns and a submission was forwarded in October, 1981.

(e) Miscellaneous Issues

B.C. Hydro has proposed a coal-fired power plant for Hat Creek (west of Ashcroft). The thermal power development will require substantial volumes of water, which would place additional demands on the Thompson River flow and consequently

increase the potential for adverse impacts from Ashcroft domestic sewage which is discharged into the Thompson River. The potential effects of acid precipitation from the facility are the subject of review by a Federal Regional Screening and Coordinating Committee chaired by the Environmental Protection Service (EPS). Membership in the Task Force includes DFO, IPSFC, EPS, Canadian Forest Service, Canadian Wildlife Service and the Atmospheric Environment Service (AES). The Terms of Reference for the Task Force are as follows (Samis, pers. comm).

1. To review B.C. Hydro's environmental impact statement and supporting documents and prepare a critique of all issues within the mandates of DFO and DOE.

2. To coordinate investigations by the represented agencies of impacts not satisfactorily addressed by B.C. Hydro.

3. To provide a forum for the benefit of senior Federal departmental managers to prepare and review recommendations.

4. To prepare technical material for presentation to regulatory or environmental review bodies such as the B.C. Utilities Commission as required by senior Federal departmental managers.

The Terms of Reference also address concerns associated with groundwater, solid waste, siltation, acid runoff, mine construction, roadway and transmission lines.

DFO and IPSFC are presently investigating baseline snowpack and snowmelt, and pH and alkalinity levels in a number of lower order interior salmon streams within the potential area of influence of Hat Creek emissions. AES has produced a long range air transport model to predict the effects of Hat Creek emissions on regional air quality. The Federal Task Force is to make a presentation of their findings at the 1982 B.C. Utilities Commission hearings.

In 1977, Afton mines Limited received a permit from the Pollution Control Branch to discharge effluent from a large copper mine-mill-smelter complex west of Kamloops. DFO has

expressed concern about the potential for water quality degradation resulting from tailings pond seepages and the release of air contaminants such as mercury, acid-producing sulfur dioxide and heavy metals. Under the terms of the permit, an intensive monitoring program (soil, vegetation, fish, small mammals) is being carried out. Further DFO concerns may be presented once the results of this program are available (Canada, DFO, Unpublished files).

(f) Linear Transportation

The Thompson River is paralleled by several linear transportation routes - the Canadian National and Canadian Pacific Railway lines, Trans-Canada Highway, oil and gas pipelines and power transmission lines.

Construction and maintenance activities (eg. clearing of right-of-ways, water course stabilization and channelization projects and improper culvert installation) cause bank erosion, siltation and channel and riverbed alteration and ultimately, can reduce available aquatic habitat, obstruct fish passage and degrade water quality. Dredging, dock construction and spills associated with the use of the mainstem Thompson River and Kamloops Lake as transportation routes can impact fish spawning, rearing and migration.

Linear transportation routes are a potential source of aquatic pollution from accidental spills of hazardous substances or debris. Also of concern are the immediate and residual effects of chemicals used for routine route maintenance work (eg. herbicides, de-icers, bridge paint). A joint CNR/Federal Government project to study the transportation of hazardous cargo and potential spills along CN's British Columbia mainline was initiated in 1980. The preliminary draft report (Sherwood and Chorney, 1980) identifies resources adjacent to the route, types of hazardous chemicals transported, the frequency of transportation and potential spill sites. Three "secondary" sites of potential concern (sites with two mainline derailments) were identified along the Thompson River between Lytton and Kamloops.

B. NORTH THOMPSON SUB-BASIN

1. Introduction

The North Thompson Sub-basin includes the mainstem North Thompson River from its origin in the Cariboo Mountains to its confluence with the South Thompson River at Kamloops and its associated salmon-supporting tributaries. A further division of the Sub-basin into lower and upper regions was made for discussion purposes (Figure 4). Area 1 includes the lower North Thompson mainstem and all salmon supporting tributaries downstream of the confluence of the Thompson and Clearwater Rivers. Area 2 includes the mainstem North Thompson and all salmon streams upstream of the Clearwater River confluence.

The average annual escapement (1969-1978) of salmon to the North Thompson Sub-basin is approximately 4600 chinook, 9100 coho, 5900 sockeye and 150 pinks (Appendix IIB), while the region's annual contribution to the commercial and Georgia Strait tidal sports fisheries (in terms of net wholesale value, $1978) is, $624,000 ($446,000 - Canada; $178,000 - USA) and $493,000, respectively.

SEP has proposed the construction of a major facility to enhance coho and chinook stocks in the upper North Thompson area. Although the exact location for the new hatchery is yet to be determined, Finn Creek is a likely candidate for the facility (Steele, pers. comm.).

Logging and ranching activities have had a widespread effect on many watercourses in the North Thompson Sub-basin. Impacts on fish resulting from urban development, sawmilling operations and recreational activities are minimal in the Sub-basin at this time. The potential for aquatic contamination and destruction to fish or fish habitat exists along most streams in the Sub-basin due to the presence of highways, railways, pipelines and transmission lines which parallel the North Thompson River.

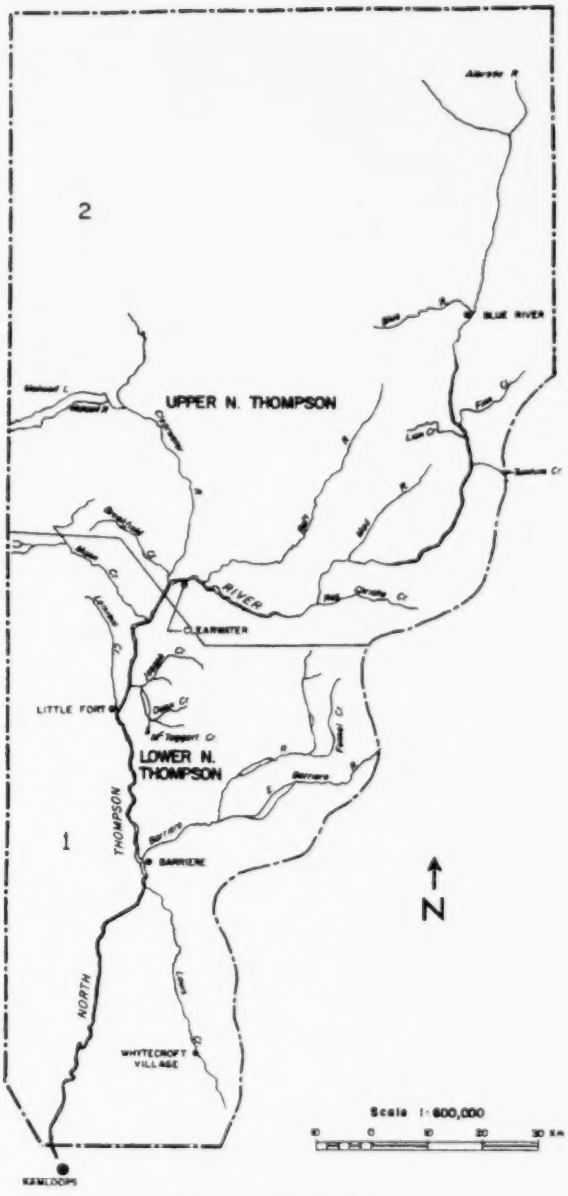

FIG.4 NORTH THOMPSON SUB-BASIN.

2. Lower North Thompson (Area 1)

(a) Fishery Resources

(i) Escapements

The lower North Thompson area (Area 1) encompasses the mainstem North Thompson River and its tributaries downstream of the Clearwater River to Kamloops (Figure 4). Chinook, coho and sockeye salmon spawn in the lower North Thompson mainstem and its five major tributaries - Louis, Dunn/Joseph, Lemieux and Mann Creeks and the Barriere River system.

Salmon escapements for the Sub-basin are presented in Appendix IIB. The average annual escapement for the lower North Thompson River System (Area 1) is 5200 coho, 1800 chinook and 1700 sockeye.

The ten year average (1969 to 1978) annual escapements to the North Thompson River mainstem are 1700 chinook, 1000 coho and 360 sockeye. During this period, the maximum number of sockeye spawners recorded was 1350 in 1977. The same year, 150 pink salmon were noted in the mainstem North Thompson River, marking the first occasion that pinks have been observed in the Sub-basin. Chinook, coho and sockeye utilizing the mainstem river spawn largely in the lower North Thompson between Little Fort and Blackpool, south of Clearwater.

Louis Creek provides spawning area for an average annual escapement of 2000 coho and about 100 chinook. Chinook generally spawn in the section of Louis Creek 10 to 16 km upstream of its confluence with the North Thompson River, while coho spawn throughout the upper reaches. The primary coho spawning area is adjacent to Whytecroft Village.

The Barriere River system includes Fennel Creek, East Barriere and Barriere Rivers and North Barriere Lake. Average annual escapements to this system are 30 chinook, 960 coho and 1300 sockeye salmon. Except for an average of approximately 30

sockeye spawners in the Barriere River, all sockeye within the Barriere system spawn in Fennell Creek. The maximum escapement of sockeye salmon to Fennel Creek during this ten year period was approximately 4100, which occurred in both 1975 and 1976. Juvenile sockeye salmon from the Barriere system rear for a year or more in North Barriere Lake, while progeny of mainstem North Thompson and Raft River sockeye spawners migrate downstream to Kamloops Lake to rear.

The Dunn/Joseph Creek system (including McTaggart Creek), supports an average annual escapement of 450 coho. Lemieux Creek supports an average annual escapement of 800 coho which spawn 5 to 8 km from the mouth of the stream. A small annual run of 50 coho spawn in Mann Creek.

(ii) Fishery Resource Utilization

The lower North Thompson salmon stock's contribution to the Canadian commercial fishery is estimated at $184,000 (net wholesale value in $1978), while another $72,500 can be linked to the American fishery (Table IV). Lower North Thompson stocks taken in the Georgia Strait tidal sport fishing are valued at $227,000. The North Thompson mainstem accounts for 45% of these values, with the remainder originating from Louis Creek (22%), the Barriere Creek system (17%), Lemieux Creek (9%) and other streams (7%).

At present, a ban exists on salmon sport fishing in the North Thompson River and all of its tributaries except for the mainstem downstream of Barriere, where a single hook regulation is enforced. No native food fishing for salmon exists within Area 1.

Chinook, coho and sockeye spawning areas are located throughout the north fork of the Barriere River downstream of North Barriere Lake and in the 6 km stretch of the Barriere below the north-east fork confluence. The Barriere River sockeye stock has historically been affected by Indian traps (1900), a storage

TABLE IV NORTH THOMPSON SUB-BASIN RESOURCE UTILIZATION

North Thompson Sub-Basin	Species	Escapement 1969-78 Avg. (6)	Commercial Fishery: Canadian # Fish (1)	Commercial Fishery: Canadian Net Wholesale $1978 (1)	Commercial Fishery: American # Fish (1)	Commercial Fishery: American Net Wholesale $1978	Sport Fishery Tidal # Fish (2)	Sport Fishery Tidal $ 1978 (3)	Native Food Fishery # Fish (4)	Native Food Fishery $ 1978 (4)	Total Value $ 1978
AREA 1	Chinook	1,799	6,332	82,886	1,151	15,067	5,757	121,358	--	--	219,311
	Coho	5,228	6,744	66,024	3,450	33,776	5,019	105,801	--	--	205,601
	Sockeye	1,697	3,937	34,370	2,647	23,108	--	--	--	--	57,478
	Pink	150	273	1,054	147	567	--	--	--	--	1,621
	Total	8,874	17,286	184,334	7,395	72,518	10,776	227,159	--	--	484,011
AREA 2	Chinook	2,776	9,772	127,915	1,776	23,248	8,883	187,254	6	78	338,495
	Coho	3,904	5,036	49,302	2,577	25,229	3,748	79,008	27	264	153,803
	Sockeye	4,168	9,670	84,419	6,502	56,762	--	--	--	--	141,181
									67[7]	259[7]	259
	Total	10,848	24,478	261,636	10,855	105,239	12,631	266,262	100	601	633,738
Sub-Basin Total	All Species	19,722	41,764	445,970	18,250	177,757	23,407	493,421	100	601	1,117,749

(1) Catch to Escapement Ratios used are: Chinook 8:1; Sockeye 4:1; Coho 3:1; Pink 2.8:1. Commercial catch (net wholesale value) is calculated from these ratios (Masse and Peterson, 1977).

(2) Barclay (1977).

(3) Based on an average of 2.7 anglers per boat and a value of $17.35 per angler day.

(4) (Bennett, 1973). These figures indicate where fish were taken, but do not indicate the origin of the fish. They are valued at commercial prices (Masse and Peterson, 1977).

(5) This is the estimated net wholesale value of these salmon if caught in the Canadian fishery. However, Canada presently receives no monetary benefits for these fish.

(6) (Masse and Peterson, 1977). The 10 year average escapement does not reflect peak spawning populations due to cyclic and dominant year patterns found in the sockeye salmon life cycle.

(7) Represents the number of Pink salmon taken by the Native food fishery.

dam (1913) and a hydroelectric diversion dam, the latter two of which were removed in 1952. Although the Barriere River contains an estimated 117,000 m^2 of spawning gravel, only small numbers of sockeye (30 annually since 1952) have utilized the area (IPSFC, 1972).

Similarly, the north fork of the Barriere has not been used extensively by spawning sockeye and has been identified as a potential enhancement site. Fennell Creek stocks, however, do pass through the area to spawn. It has been proposed that a portion of the Fennell Creek run could be diverted into an artificial spawning channel below North Barriere Lake. This brood stock could also be supplemented by planting eggs obtained from Raft River stocks.

Other possiblilities under consideraton include coho and chinook fry stocking of the upper reaches of the north Barriere River and a chinook - coho hatchery at the North Barriere Lake outlet. One particularly promising possibility, in view of future Thompson River Basin fry stocking programs, is a coho hatchery on Louis Creek (Steele, pers. comm.).

(b) Environmental Issues

The major sources of concern to DFO with respect to maintenance of Area 1 salmon populations are forest harvesting and agricultural activities.

(i) Forest Harvesting and Wood Conversion

Forest harvesting is both the primary industry and the major source of income within the North Thompson Sub-basin. However, increased logging activity in the Sub-basin has contributed to excessive silt loads and may be affecting water flow regimes on tributary streams. There is a need for better documentation of these effects and their overall impact on the fishery resource (Goodman, 1979).

Within the lower North Thompson system, extensive logging operations have been carried out on the Barriere River system and Mann Creek. All harvested logs are transported over land, and building and maintenance of access roads has often deteriorated stream habitat (Brown et al, 1979).

The potential impacts of sawmill operations on stream habitat are visible at an abandoned sawmill at the outlet of East Barriere Lake. Large amounts of mill debris have accumulated at the head of the East Barriere River, creating a migration barrier and preventing utilization of prime spawning gravel (Brown et al, 1979). Recent modernization and centralization of sawmills at Barriere and on Louis and Heffley Creeks, and relocation of mills away from salmon bearing streams have reduced the likelihood of impacts on water quality and fish habitat (Goodman, 1979).

(ii) Agriculture

Lower Lemieux Creek and Louis Creek flow through valuable farmland used for rearing cattle and cultivating winter forage crops such as alfalfa and hay. The effects of such agricultural activities on stream water quality include water withdrawal for irrigation and excessive siltation from streambank erosion and instream stock watering. Nutrient enrichment, although undocumented, may also be a problem.

(iii) Urban Development

Numerous small communities and individual residences are located along the North Thompson River and its tributaries within Area 1. The effects of the septic systems serving these communities on salmon habitat and water quality have not been quantified. Whytecroft Village on Louis Creek has the potential to degrade water quality both with septic tank seepage and nutrients from agricultural sources.

Tod Mountain Development Limited has proposed the construction of a major ski village in the Tod Mountain - McGillivray Lake area in conjunction with extensive expansion of the present

alpine ski facilities. The construction and operation of a development of the size proposed could have far-reaching effects on escapements in Louis Creek.

In addition to supporting chinook, Louis Creek is one of the best coho producers in the North Thompson River Sub-Basin. The trail clearing and grooming associated with the ski area development could produce instream siltation, smothering spawning and rearing areas. Extensive removal of forest cover could significantly modify the hydrological regime of the watershed in general and streamflow dynamics in particular. DFO is also concerned that the planned sewage disposal system may degrade water quality in McGillivray Creek, a tributary of Louis Creek. Christian Creek, another Louis Creek tributary located upstream of McGillivray, is being evaluated by SEP for groundwater sources for coho incubation. Although limited surveying of the development area and some monitoring of the runoff to McGillivray Creek has been conducted, no construction has yet taken place(Voysey, pers. comm.).

(iv) Minimum Flows

Low streamflow conditions observed in Mann, Lemieux and Louis Creeks may be natural or the result of irrigation withdrawals. Information documenting the effects of agricultural water demands on these watercourses is scanty. To illustrate, while there are at present approximately twenty irrigation licences on Louis Creek, streamflow data are available only for the 1911 to 1916 irrigation seasons and the years 1971 to 1979. Similarly, flow data for Lemieux Creek are available only for the 1926 to 1928 irrigation seasons.

The Louis Creek discharge rate averages 115 cfs annually, but ranges from 2.4 to 1530 cfs. While the lowest recorded flow in Lemieux Creek was 1.0 cfs, observed in August 1979, some reaches have dried up completely during late summer (Brown et al, 1979; Voysey, pers. comm.). Chinook salmon (which spawn in late summer) are particularly susceptible to low flows at this time. Newly issued or renewed water licences for Louis and Lemieux

Creeks include a clause restricting late summer and early fall water withdrawals. During these low flow periods, restricted licencees are obliged to record the volume of withdrawn water for local Water Rights Branch personnel. Nevertheless, enforcement of withdrawal restrictions is often difficult. It has been recommended that bio-engineering studies be carried out to establish the minimum flows required to sustain salmon production in Louis and Lemieux Creeks, and that licensed withdrawals for irrigation be enforced (Hamilton, 1980).

(v) Mining

While no mines are currently in operation near salmon-bearing waters in the lower North Thompson Sub-basin, the increased mineral exploration of the past several years could eventually lead to future mining operations in the region. For example, a large deposit of copper ore was reported in the vicinity of Barriere and exploratory work is underway to define the boundaries of the deposit. Similar work continues in other areas, such as the Dunn Lake region which was extensively surveyed during the summer of 1979 (Canada, DFO 1974-1978).

(vi) Linear Transportation

The Trans-Mountain Oil pipeline route is a potential source of pollution as the pipeline parallels and crosses major salmon-producing streams throughout the area. The company reportedly maintains satisfactory surveillance of the pipeline as well as a stockpile of spill cleanup equipment and materials at Kamloops (Canada, DFO, 1974-1978).

The Canadian National Railway follows the east bank of the North Thompson River from Kamloops to east of Clearwater, where the railway line crosses the mainstem North Thompson River. Tributary streams, including Louis Creek, Barriere River and Joseph Creek, are crossed by the railroad. A proposal by CNR to "twin" the entire length of track would likely require construction on the river side of the present railway line, introducing

the possibility of massive siltation and of water quality alteration. Highway #5 follows a similar route along the North Thompson River east bank between Kamloops and Barriere, where it crosses to the west bank. En route, the Barriere River and Lemieux, Mann and Louis Creeks are also crossed by the highway.

The location of the railway lines beside the North Thompson River also introduces the possibility of hazardous waste and debris spills. A joint CNR/Federal Government project was initiated in 1980 to examine the transportation of such goods along the British Columbia CN mainline. No specific sites of potential impact were identified along the lower North Thompson (Sherwood and Chorney, 1980).

3. Upper North Thompson River (Area 2)

(a) Fishery Resources

(i) Escapements

Area 2 of the North Thompson Sub-basin includes the North Thompson River from its origin in the Cariboo Mountains downstream to its confluence with the Clearwater River in addition to its associated salmon supporting tributaries (Figure 4). The Blue, Albreda, Raft, Mahood and Clearwater Rivers, and Lion, Finn, Tumtum, Reg Christie and Brookfield Creeks support predominantly coho and chinook stocks. The Raft River also has a large sockeye run.

Area 2 supports average annual escapements of approximately 3900 coho, 2800 chinook and 4200 sockeye (Appendix IIB), with the majority distributed in the tributaries rather than the upper North Thompson River mainstem. The Blue and Albreda Rivers in the upper watershed of the North Thompson River system have been enumerated for spawners since 1974. The estimated average annual escapements (1974-78) are 310 coho within the lower 2.5 km of the Blue River, and 130 coho in the lower 9 to 12 km of the Albreda River. Annual average escapements (1969-78) of 580 chinook and 110

coho were recorded in the lower 5 km of Finn Creek while 1200 coho were recorded in the lower 5 km of Lion Creek.

The Raft River supports an average annual escapement of 190 chinook, 540 coho and 4200 sockeye, with all three species utilizing the lower 5 km of river. A peak sockeye escapement of approximately 11,000 fish was recorded in 1972. Juvenile sockeye from the Raft River system rear in Kamloops Lake.

The Clearwater River, which lies largely within the boundaries of Wells Gray Park, has annual average escapements of 1500 coho and 1700 chinook. While coho spawn primarily in the Whitehorse Bluff area 32 km upstream of the North Thompson confluence, spawning has also been observed in the rapids 8 km from the mouth (Voysey, pers. comm.). Major chinook spawning areas are located at Whitehorse Bluff and the Horseshoe located 60 km upstream from the mouth. Two Clearwater River tributaries support additional small escapements. The Mahood River, which flows 1.6 km between Mahood Lake and Clearwater River, supports an average annual escapement of 260 chinook. Brookfield Creek had an average annual escapement for the 1969 to 1973 period of 30 coho; none have been observed subsequently.

Reg Christie and Tumtum Creeks have annual average escapements of 20 and 28 coho, respectively. Salmon have not been observed in the Mad River since 1952, when 74 coho were enumerated.

(ii) Fishery Resource Utilization

The upper North Thompson area's estimated contribution to the Canadian and American commercial fisheries, at $262,000 and $105,000 respectively, is slightly less than that of the lower North Thompson. In contrast, Area 2's contribution to the Georgia Strait tidal sport fishery is slightly higher at $266,000. The Clearwater, Mahood and Raft Rivers account for roughly 72% of these net wholesale values (Table IV).

Historically, the Native food fishery in Area 2 has depended upon sockeye salmon from the Raft River and a few chinook from other streams. In the wake of a steady decline in the Raft River sockeye escapements over the last four or five cycles, it was found necessary to institute temporary closures. There is at present no Indian food fishery within the North Thompson Sub-basin. The increased mobility of the Indian people coupled with the better relative condition of salmon captured for food in the Fraser River compared to the North Thompson River has also contributed to the high use of the Lilloett-Lytton area.

Prior to August 1978, the only area open to salmon sport fishing in the North Thompson Sub-basin was the Clearwater River and its tributaries. In 1978, regulations were altered to permit salmon fishing only in the mainstem North Thompson River downstream of the Highway #5 bridge at Barriere.

(iii) Salmonid Enhancement

Groundwater studies have been conducted on Lion and Finn Creeks to determine possible locations for the proposed North Thompson enhancement facility. Finn Creek appears to be a likely choice (Steele, pers. comm.). Coho and chinook stocks from Finn Creek, Blue River and Lion Creek are being considered as possible egg donors for the new hatchery. In addition, colonization of underutilized portions of Finn Creek with coho, chinook and steelhead is being considered. Blue River is also underutilized and stocking of both accessible and inaccessible areas with chinook and coho could increase production.

Improved access past Porte d'Enfer canyon (between Blue River and Avola) could open up a large area to stocks. Other significant enhancement opportunities include hatcheries on the Clearwater or Mahood Rivers (for chinook, coho and steelhead) and in the Avola vicinity. There is potential for a coho-chinook hatchery on the Raft River although water supply may be a problem.

(b) Environmental Issues

(i) Forest Harvesting and Wood Conversion

Impacts due to increased logging activity in the upper watersheds are the major source of concern in the North Thompson Sub-basin. The total logged area in the Clearwater Fisheries Sub-district has increased by a minimum of 10% annually since 1974 (Canada, DFO 1974-1978). At present, logs are transported to sawmills via logging truck and subsequently stored on dry land. The construction and maintenance of a network of access roads for clearing operations has seriously impacted the fishery resource, especially on Lion and Finn Creeks and the Raft River. Problems associated with flow fluctuations, streambank erosion, scouring and siltation of streambeds, stream and channel diversions, log jams and debris accumulation have been observed on the latter watercourses (Brown et al, 1979; Canada, DFO 1974-1978; Goodman, 1979).

Logging in the upper watersheds of the Blue and Albreda Rivers began in 1977, and the watershed of the North Blue River will be logged in the near future. The recent trend toward modernization and centralization of North Thompson Sub-basin sawmills has reduced the potential for water quality and habitat degradation. New sawmills at Vavenby, Blue River and Clearwater, for instance, do not handle or store logs on or near adjacent watercourses (Goodman, 1979).

Coho runs to Brookfield Creek, a small tributary of the Clearwater River, may have been eliminated by previous sawdust deposition (from a sawmill) within the spawning areas and spawning gravel removal during spring freshet floods over the lower 0.8 km (Brown et al, 1979).

(ii) Agriculture

Agricultural activity is limited in the upper North Thompson area. Within the lower portion of the Raft River, uncontrolled access of cattle to spawning areas has resulted in streambank

erosion, silt loading and possibly nutrient enrichment (Goodman, 1979).

(iii) Minimum Flows

The Mad River and Brookfield, Reg Christie and Tumtum Creeks possess unstable flow regimes characterized by naturally occurring low flows and periodic flash floods during spring freshet. The streambeds of these watercourses, with the exception of Tumtum Creek which flows through a swamp, are composed of boulders and bedrock which make them unsuitable for salmon production. Spawning areas tend to be restricted to the lower 0.5 km of these streams. Drastic flow fluctuations as well as high silt loads observed in the Raft River and Finn and Lion Creeks may be associated with the logging activities within these watersheds. Elevated water temperatures (including summer temperatures of 21°C) have been recorded on the Raft River (Voysey, pers. comm.). Probably a consequence of the low flows and the Raft's watershed characteristics, these high temperatures have been implicated in the mortality of spawning sockeye salmon. In 1963, it was estimated that 43% of the sockeye run died from high water temperatures before spawning (Brown et al, 1979).

Partially isolated from development within Wells Gray Park, the Clearwater River system contains several lakes which act as storage reservoirs to stabilize stream flows. The potential for impacts on the fisheries resources due to development of the proposed System E hydroelectric dam is a source of concern (Canada, DFO, 1974). Increased logging activity in the Blue River watershed could alter stream flow characteristics.

(iv) Urban Development

The effects on receiving water quality of septic field effluents from the many small North Thompson communities have not been assessed quantitatively. The largest community, Clearwater, is located approximately 90 km north of Kamloops. To avoid direct sewage discharge into the North Thompson River, Clearwater

recently installed an evaporation sewage treatment system with impermeable lagoons for one of its new subdivisions (Goodman, 1979; Voysey, pers. comm.).

(v) Linear Transportation

The Trans-Mountain Oil Pipeline within Area 2 parallels the North Thompson River and Lemieux Creek and also crosses a number of spawning streams. During construction of the line in 1950, siltation was reported on several streams. Present-day surveillance and maintenance of the line has apparently been satisfactory (Brown et al, 1979).

Highway #5 and the Canadian National Railway parallel the North Thompson and Albreda Rivers, with highway crossings located on the Albreda, Mad and Raft Rivers and Tumtum, Finn and Brookfield Creeks. There are numerous railway crossings over the North Thompson River and one crossing over Lion Creek. To improve fish passage, a fish baffle was installed at the small falls below the railway culvert on Lion Creek.

As noted under the Linear Transportation section for North Thompson Area 1, the proposed twinning of the railway line is a major concern to DFO. The transportation of hazardous materials along the British Columbia CNR Mainline has been studied in a joint CNR/Federal government report begun in 1980. The draft document identifies one secondary site of concern within Area 2, immediately north of Finn Creek (Sherwood and Chorney, 1980).

(vi) Mining

Birch Island, a small community on the mainstem North Thompson River, is the proposed site for a uranium mine. Plans to proceed with further exploration and operation are under review, but development may be delayed because of a seven year B.C. Government moratorium on uranium exploration and mining. DFO opposed the original mining proposal because of the potential effects of radionuclides and other pollutants from mining and

mine-milling operations on fish and water quality in the North Thompson River (Canada, DFO, 1977).

Dimac Resource Corporation has recently commenced tungsten mining operations on Maxwell Creek, a tributary of the Raft River. The company proposes to discharge a maximum 65,000 IGPD of mine tailings to an impoundment, with recycling of supernatant and no positive discharge to either Maxwell Creek or the Raft River. Although salmon do not presently utilize either of the latter watercourses in the vicinity of the mine, the lower Raft River does provide habitat for chinook, coho and sockeye. Moreover, the potential exists for extending the spawning range to the middle sections of the Raft above the falls. Accordingly, concern has been expressed over the possibilities of pond failure and subsequent tailings deposition into these watercourses and over the potential for sedimentation from the open pit. On October 28, 1981, Dimac was granted a Pollution Control Permit for the tailings discharge and open pit runoff. The Permit requires Dimac to conduct sampling and monitoring of Maxwell Creek, the tailings pond and pit drainage (Canada, DFO, Unpublished files).

C. SOUTH THOMPSON/SHUSWAP SUB-BASIN

1. Introduction

The South Thompson/Shuswap Sub-basin provides spawning and rearing areas for chinook, coho, sockeye and pink salmon. Average annual escapements to the spawning streams and lakeshore areas in this Sub-basin are close to 550,000 salmon, equivalent to 71% of the Thompson Basin total. The principal environmental problems are associated with urban and recreational land development, forest harvesting and agriculture.

The Sub-basin has been divided geographically into the five areas described below (and shown in Figure 5) to facilitate discussion of fishery resources and environmental concerns.

Area 1. The river systems entering Shuswap Lake at Sicamous
- a) The Eagle River drainage
- b) The Shuswap River drainage
- c) The Bessette Creek system.

Area 2. The Salmon River system and Tappen and Canoe Creeks, which both enter the Salmon Arm of Shuswap Lake.

Area 3. The Shuswap Lake system and its major tributaries

Area 4. The Adams Lake system.

Area 5. The South Thompson River system.

2. Eagle River Drainage (Area 1a)

(a) Fishery Resources

i) Escapements

The Eagle River arises near Revelstoke and flows west for 60 km before entering Shuswap Lake at Sicamous Narrows. Average annual escapements (1969 to 1978) to the Eagle River are approximately 1800 coho, 50 sockeye and 420 chinook salmon. Spawning occurs in the Eagle River from its confluence with the Perry River upstream to Griffin Lake, 10 km above Taft. Between 20 and 50 coho have spawned annually in the lower 0.8 km of South Pass

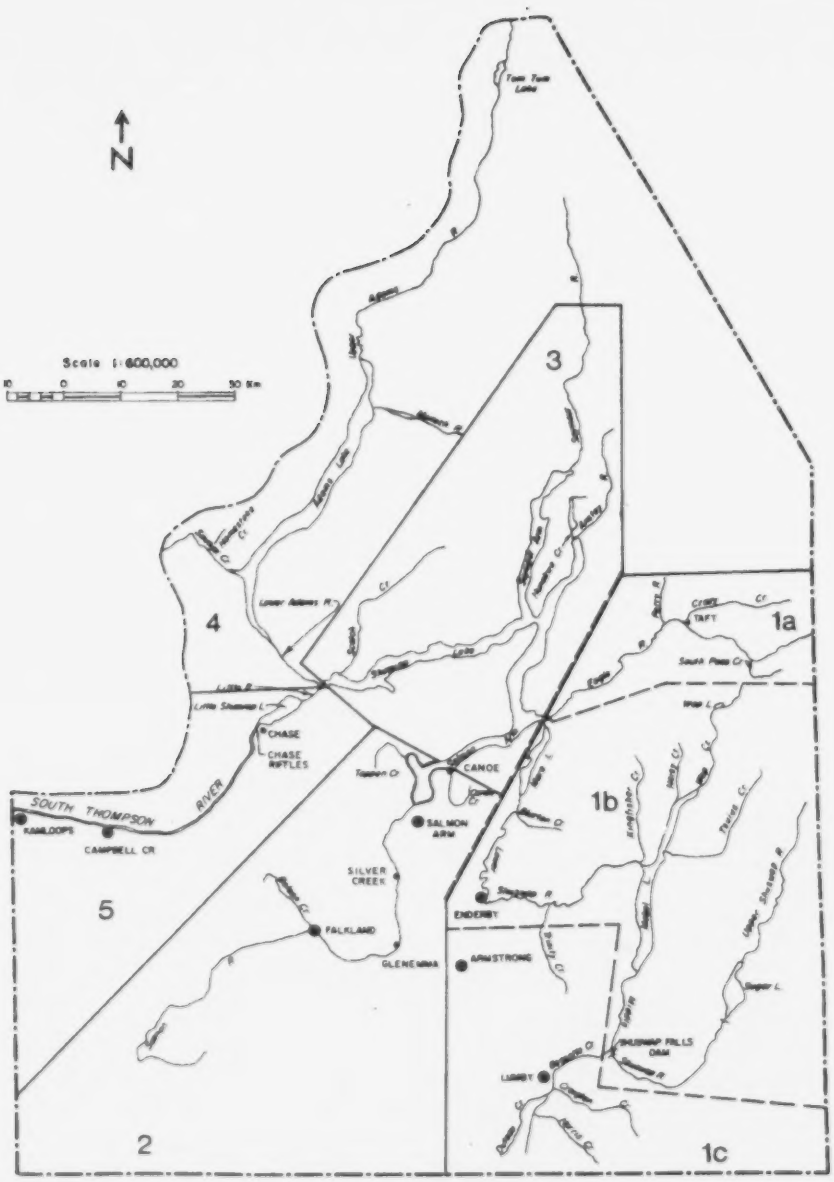

FIG. 5 SOUTH THOMPSON / SHUSWAP SUB-BASIN.

Creek (included with Eagle River escapements). Escapements of coho salmon to the Eagle River system represent 32% of the total coho escapement to the South Thompson/Shuswap Sub-basin (Appendix IIC).

(ii) Fishery Resource Utilization

Eagle River and South Pass Creek coho, sockeye and chinook escapements are estimated to contribute annual net wholesale values (Canadian $) equivalent to $43,000 for the Canadian commercial fishery, $16,000 for the American commercial fishery and $64,000 for the Georgia Strait tidal sport fishing (based on Table V figures) . Salmon sport fishing is prohibited and no Native food fishery exists in the area. Stocks are open to interception in sport and Native food fisheries downstream in the Lower Thompson River below Shuswap Lakes and in the Fraser River.

(iii) Salmonid Enhancement

A small scale private trout hatchery located east of Crazy Creek, which operated up to the mid 1970's, is under new management and is being rebuilt as a commercial fish farm (Cartwright, pers. comm.). The continued operation of a small scale trout hatchery at Taft, funded by the B.C. Government, remains uncertain.

In recognition of the potential for chinook and coho enhancement in the Eagle River system, a modern hatchery facility at Crazy Creek has been proposed by SEP (Shepherd, pers. comm.). Several factors render Crazy Creek as an attractive site for a major hatchery, including the availability of native coho and chinook donor stocks, a gravity-fed water supply, as well as a groundwater supply and suitable areas for the construction of rearing channels and ponds. A proposed expansion of the present pilot project includes installation of portable troughs and above ground rearing ponds for one million chinook and coho eggs (Canada, DFO, 1982).

TABLE V SOUTH THOMPSON/SHUSWAP SUB-BASIN RESOURCE UTILIZATION

South Thompson Sub-Basin	Species	Escapement 1969-78 Avg. (6)	Commercial Fishery Canadian # Fish (1)	Canadian Net Wholesale $1978 (1)	American # Fish (1)	American Net Wholesale $1978	Sport Fishery Tidal # Fish (2)	Sport Fishery Tidal $ 1978 (3)	Native Food Fishery # Fish (4)	Native Food Fishery $ 1978 (4)	Total Value $ 1978
AREA 1	Chinook	9,080	31,962	418,382	5,811	76,066	39,056	692,508	147	1,924	1,188,872
	Coho	3,589	4,527	44,319	2,316	22,674	3,369	71,019	8	78	138,090
	Sockeye	36,325	84,274	735,712	56,667	494,703	--	--	471	4,112	1,234,527
	Total	48,914	120,763	1,198,413	64,794	593,443	32,425	683,519	626	6,114	2,481,489
AREA 2	Sockeye	155	360	3,143	242	2,113	--	--	--	--	5,256
	Chinook	230	810	10,603	147	1,924	736	15,515	--	--	28,042
	Coho	1,327	1,712	16,760	876	8,576	1,274	26,856	--	--	52,192
	Total	1,712	2,882	30,506	1,265	12,613	2,010	42,371	--	--	85,490
AREA 3	Chinook	5	18	236	3	39	16	337	--	--	612
	Coho	113	146	1,429	75	734	108	2,277	--	--	4,440
	Sockeye	23,151	53,710	468,888	36,116	315,293	--	--	--	--	784,181
	Total	23,269	53,874	470,553	36,194	316,066	124	2,614	--	--	789,233
AREA 4	Chinook	1,760	6,195	81,092	1,126	14,739	5,632	118,723	--	--	214,554
	Coho	589	760	7,440	389	3,808	565	11,910	--	--	23,158
	Sockeye	425,907	988,104	8,626,148	664,415	5,800,343	--	--	--	--	14,426,491
	Pink	115	209	807	113	436	--	--	--	--	1,243
	Total	428,371	995,268	8,715,487	666,043	5,819,326	6,197	130,633	--	--	14,665,446
AREA 5	Chinook	5,450	19,186	251,119	3,488	45,658	17,440	367,635	--	--	664,412
	Sockeye	43,660	101,291	884,270	68,110	594,600	--	--	--	--	1,478,870
	Pink	330	601	2,320	323	1,247	--	--	--	--	3,567
	Total	49,440	121,076	1,137,709	71,921	641,505	17,440	367,635	--	--	2,146,849
I.P.S.F.C. Misc. Runs	Sockeye	21,295	49,404	431,297	33,228	290,010	--	--	--	--	721,307
Sub-Basin Totals	All Species	573,001	1,343,267	11,983,965	873,437	7,672,963	58,196	1,226,772	626	6,114	20,889,814

(1) Catch to Escapement Ratios used Are: Chinook 6:1; Sockeye 4:1; Coho 3:1; Pink 2.8:1. Commercial catch (net wholesale value) is calculated from these ratios (Massa and Peterson, 1977).

(2) Barclay (1977).

(3) Based on an average of 2.7 anglers per boat and a value of $17.35 per angler day.

(4) (Bennett, 1973). These figures indicate where fish were taken, but do not indicate the origin of the fish. They are valued at commercial prices. (Massa and Peterson, 1977).

(5) This is the estimated net wholesale value of these salmon if caught in the Canadian fishery. However, Canada presently receives no monetary benefits for these fish.

(6) (Massa and Peterson, 1977). The 10 years average escapement does not reflect peak spawning populations due to cyclic and dominant year patterns found in the sockeye salmon life cycle.

(b) Environmental Issues

(i) Forest Harvesting and Wood Conversion

In the past, intensive logging and access road construction in the upper watersheds of Perry River, English Creek and South Pass Creek have caused considerable erosion and siltation in watercourses downstream of these areas. As second growth timber becomes available for harvesting in the South Pass Creek drainage, further siltation due to logging may become a problem. The Perry River watershed is presently one of the most actively logged drainages in the area. Continued intensive logging may result in the silt-loading of downstream salmon-bearing watercourses such as the Eagle River. Poor logging road construction practices are the major cause of siltation in the system. DFO recently prosecuted a company for destruction of Eagle River salmon spawning habitat which occurred when sand, silt and other debris from road construction entered the stream (Canada, DFO, 1974-1978).

Water quality degradation has also been associated with a sawmill operation in the lower portion of the Eagle River, where hogfuel leachate was noted entering a tributary. The problem was resolved by collecting and containing the leachate on site (Canada, DFO, Unpublished pollution files).

(ii) Agriculture

Below Malakwa, the character of the Eagle River changes from the steeper gradient typical of its upper reaches to a slower, meandering pattern. This flatland zone, especially near its confluence with Shuswap Lake, has been developed for agricultural purposes. Erosion and flood protection measures (e.g. riprapping) and irrigation diversions have been the source of some minor problems in the lower Eagle River and the adjacent areas of Shuswap Lake. Nutrient enrichment may also be occurring but has not been confirmed. Although salmon spawning is restricted to the Eagle River system above Perry River, the lower reaches of the system are utilized for rearing and migration. Agricultural fertilization, increased sewage and industrial discharges may accelerate eutrophication within the Salmon Arm of Shuswap Lake.

(iii) Urban Development

The only significant concentration of dwellings within the system is located at Sicamous, where septic tank effluent seeps into both the Eagle River and Sicamous Narrows. The effects of these non-point discharges have not been determined.

The concentrated boating activity within Sicamous Narrows during the summer tourist months has the potential to increase hydrocarbon and domestic waste deposition into Shuswap Lake. In many areas, existing wharves traverse foreshore grass beds and infringe upon excellent juvenile salmon habitat. Future moorage development along the Narrows will be limited to floating wharves with overhead walkways (B.C. Department of Lands, Parks and Housing, 1979), which should minimize further disturbance of these productive areas. Further discussion of Sicamous Narrows as a rearing habitat and a migratory route for Shuswap River system salmonids may be found in Section II C. 5 (Shuswap Lake).

(iv) Linear Transportation

Between Revelstoke and Sicamous, both Highway #1 and the Canadian National Railway follow the Eagle River. Environmental impacts associated with these transportation routes may result from construction and maintenance activities or the accidental spillage of hazardous cargo into watercourses.

3. Shuswap River Drainage (Area 1b)

(a) Fishery Resources

(i) Escapements

The Shuswap River system includes the Upper, Middle and Lower Shuswap River, Blurton, Wap, Trinity, Noisy, Tsuius, and Kingfisher Creeks; and Sugar, Wap and Mabel Lakes. Average annual salmon escapements to the system are 830 coho, 8600 chinook and 37,000 sockeye (Appendix IIC).

Within the Middle Shuswap River, an escapement of 11,000 sockeye was recorded during the 1978 dominant cycle year, a substantial increase over the 3000 sockeye recorded for the 1974

brood year. Salmon spawning occurs 16 to 22 km upstream of Mabel Lake. Although 30 km of excellent spawning grounds have been identified further upstream, a B.C. Hydro dam at Shuswap Falls physically obstructs migration.

Wap Creek, which flows into the northern section of Mabel Lake, has an average annual escapement of 190 coho. These fish spawn between 5 km below and 5 km above Wap Lake, where a set of impassable falls prevents further upstream migration. The Lower Shuswap River flows west from Mabel Lake and then north into Mara Lake. Average annual escapements to this river are 8100 chinook, 240 coho and 34,000 sockeye. A dominant year escapement of 190,000 sockeye was recorded in 1978, more than double the 1974 brood year figure. Blurton Creek, a small tributary of the Lower Shuswap had annual escapements of 10 to 40 coho between 1976 and 1978 (Appendix IIC). The majority of sockeye from Middle Shuswap River rear in Mara and Shuswap Lakes, with small numbers in Mabel Lake (IPSFC, 1972).

Both Mara Lake and Sicamous Narrows nearshore zones provide important rearing habitat for juvenile sockeye from the Lower and Middle Shuswap River (Figure 5). Rearing and spawning distribution patterns often coincide for juvenile coho and chinook salmon although the latter may also rear in Mabel and Mara Lakes (Graham and Russell, 1979b).

(ii) Fishery Resource Utilization

The net wholesale value of Canadian commercial fish catches derived from Area 1b is estimated at $877,000 compared to $534,000 in the U.S. fishery. Shuswap stocks taken in the Georgia Strait tidal sport fishery are valued at $214,000. The Lower Shuswap accounts for the greater portion of these catches (Table V).

Chinook sport fishing in the Lower and Middle Shuswap Rivers is closed from September 1 to October 31 each year. A single hook regulation is enforced on the rivers from Shuswap Falls downstream to Mara Lake (Canada, DFO, 1974-1978). Mabel and Mara Lakes are exempted from the regulation between July 15 and November 30. Sockeye and chinook salmon are taken from the Lower Shuswap River in the Native food fishery.

(iii) Salmonid Enhancement

Middle Shuswap River

Mabel Lake possesses sufficient rearing habitat to support the progeny of an estimated 270,000 spawned sockeye salmon, but is presently underutilized by the Middle Shuswap River stocks (the 1978 escapement was 11,000 sockeye). In 1954, more than one million eyed sockeye eggs were transplanted from the Adams River to the Middle Shuswap. This transplant is believed responsible for the increased escapement of 1958 and subsequent cycle years (IPSFC, Annual Reports 1969 to 1978). Further enhancement of these sockeye stocks will likely result in more efficient use of potential spawning and rearing territories in the Middle Shuswap River and Mabel Lake areas.

Two B.C. Hydro dams are located on the Middle Shuswap River. The first, situated at the outlet of Sugar Lake, provides flow control for the lower dam and powerhouse situated at Shuswap Falls. While historically, habitat above the lower dam (now impassable to migrants) supported chinook salmon, no immediate plans for enhancement are anticipated due to the present focus on activity downstream. An enhancement facility below the Shuswap Falls does seem feasible and is under consideration (Steele, pers. comm.).

Lower Shuswap River

In an on-going program initiated in 1979, 72,000 downstream migrant chinook fry were captured in the Lower Shuswap River, coded-wire tagged and released. As part of a feasibility study for enhancement possibilities in this region 1981 to 1983 returns will be analyzed. In 1978, the Lower Shuswap River sockeye run was double that of 1974 and likely the largest run since 1900. This suggests that sockeye runs may steadily increase towards historic levels. The feasibility of a proposed hatchery site for chinook and coho immediately downstream of Mabel Lake has been examined and appears promising.

(b) Environmental Issues

(i) Forest Harvesting

Intensive logging and access road construction has increased siltation in the Upper Shuswap River watershed. To date, these silt loads have had little effect on salmon due to the absence of migrants upstream of the Shuswap Falls dam. Siltation could become a problem if stock recolonization occurs above the falls. Siltation due to logging activity has also occurred in Kingfisher, Tsuius and Noisy Creeks. Degraded water quality could result in the Lower Shuswap River (Canada, DFO, 1974-1978; Kurtz, pers. comm.).

Logging in the upper watershed of Wap Creek is the chief threat to salmon utilizing the creek immediately downstream and upstream of Wap Lake. Aftereffects documented include log jams, debris accummulation, erosion and channelization (Brown et al, 1979).

(ii) Agriculture

Alfalfa cultivation, dairy farming and hog production are the principal agricultural activities in the low lying areas of Blurton Creek and the Lower and Middle Shuswap Rivers. Although livestock feeding and watering occurs throughout the area, the Shuswap River's relatively large discharge rate (ie. 20,000 cfs) has prevented excess nutrient enrichment. Nonetheless, future agricultural growth, particularly in dairy farming, may increase the incidence of bank erosion, sedimentation and nutrient loading associated with livestock watering and land clearing operations. The expected increase in erosion protection measures (eg. dyking, channelization, rip-rapping) could lead to changes hn streamflow regimes and removal of stream bank vegetation.

(iii) Minimum Flows

B.C. Hydro's Shuswap Falls dam exerts a significant impact on Shuswap River salmon stocks. Upstream, habitat formerly available to chinook salmon is now inaccessible, while downstream, gravel lost is not being replenished from above the dam (Hamilton, pers. comm.). Downstream flows fluctuate radically and have been reduced to below the historic lowest levels.

Prior to the early 1970's, the flushing of water through the sluice gates approximately every five years to alleviate high silt accumulations behind the dam resulted in high fish mortalities downstream. More recently, accumulated sediment has been dredged and deposited back into the river, with the proviso that concentrations not exceed natural levels (Kurtz, pers. comm.).

Automatic power shutdown at Shuswap Falls may occur several times each year during transmission failures or other emergency situations. These shutdowns result in a temporary and severe drop in the water level downstream. Recently, the environmental repercussions of the shutdowns have been studied by DFO and B.C. Hydro (Canada, DFO, 1980). The potential for impact is greatest during the spring and summer, when large numbers of juvenile salmon are present and water temperatures are normally high. The stranding of juveniles is the greatest potential impact of such low flows. Preliminary results of the study indicate that the severity of effects related to the shutdown decreases with distance downstream. The present shutdown procedures minimize downstream dewatering, but it seems unlikely that shutdowns can be prevented entirely under the existing B.C. Hydro network operating conditions (Hamilton, pers. comm.).

The problems described above have contributed to the decline of salmon utilizing the Middle Shuswap River. Expensive modification to or abandonment of the Shuswap Falls power station may be the only solutions to this fishery problem.

(iv) Urban Development

The Corporation of the City of Enderby currently holds a Waste Management Branch permit (PE 203) allowing the discharge of chlorinated sewage to the Lower Shuswap River. In view of the valuable salmon resource of the Shuswap River and the toxicity of residual chlorine, both DFO and the IPSFC recommended that dechlorination of the effluent be a requirement of the permit (Canada, DFO, Unpublished pollution files). As of January 1982, the condition had not been added to the permit. On October 21, 1981, the City applied for a downgrading of the BOD and suspended solids requirements (Forty, pers. comm.).

There is limited residential development in the Mabel Lake area, and the vicinity of Mara Lake is only moderately populated. It is probable that in the near future these regions will become developed with permanent residential housing, summer cottages and marinas. Mara Lake has the potential to become a valuable salmon rearing area, particularly if Middle Shuswap River sockeye stocks are enhanced. It is therefore crucial that lakeshore development and nutrient loading (e.g. from sewage discharges) be carefully controlled if current salmon populations are to be maintained.

(v) Linear Transportation

The Canadian Pacific Railway and Highway #97A follow the Lower Shuswap River from Enderby to Mara Lake. Their proximity to the river increases the likelihood of spills of hazardous wastes and debris. The potential for impacts along the route of the proposed Merritt - Kamloops highway extension through Area 1b (notably near Mabel Lake and Wap Creek) also exists. In 1977, erosion from a B.C. Hydro power transmission right-of-way which crosses Wap Creek above Wap Lake caused heavy silting in a downstream spawning area (Brown et al, 1979).

(vi) Aquatic Weed Control

Eurasion water milfoil (Myriophyllum spicatum) has become established in many lakes of the Okanagan Valley and Lower Mainland and only recently has spread to Salmon Arm within Shuswap Lake. Outbreaks have been observed at Sicamous Narrows, Glenedden, Sand Point Marina and Canoe. The District of Columbia has applied to the Provincial Pesticide Control Branch for authorization to treat a total of 20 hectares in Salmon Arm and Mara Lake with 2,4-D BEE (Patterson, pers. comm.)

4. Bessette Creek System (Area 1c)

(a) Fishery Resources

(i) Escapements

Bessette Creek and its tributaries - Duteau, Creighton and Harris Creeks, are important coho producing streams in the South

Thompson/Shuswap Sub-basin (Figure 5). Average annual escapements to the Bessette Creek watershed are 920 coho and 15 chinook (Appendix IIC). Duteau Creek supports 70 to 80% of Area C coho stocks, while the majority of chinook spawn in Bessette Creek below Lumby. Although spawning and rearing areas roughly coincide, the latter are generally dispersed further upstream and downstream. A small number of kokanee (land-locked salmon) and resident trout also inhabit the Bessette Creek system.

(ii) Fishery Resource Utilization

Bessette Creek stocks contribute annual net wholesale values of $109,000 to Canadian commercial fisheries, $20,000 to American commercial fisheries and a further $159,000 to the Georgia Strait tidal sport fishery (Table V). Bessette Creek and its tributaries are closed to salmon sport fishing year round, and a Native food fishery does not exist in the area.

(iii) Salmonid Enhancement

The potential exists for chinook and coho enhancement in the Bessette Creek watershed. Construction of small fishways, stream clearance projects and the installation of fences to protect greenstrips and reduce livestock access would enhance existing stocks. Habitat degradation by agricultural and forestry-related activities make this system unsuitable for a major salmon enhancement facility at the present time (Shepherd, pers. comm.).

(b) Environmental Issues

(i) Forest Harvesting and Wood Conversion

Logging operations in the upper drainages are likely responsible for the water shortages and fluctuating water levels observed in the lower Bessette Creek system. Drastic changes in flow (particularly during the freshet period) have resulted in streambed scouring and streambank erosion. Available rearing habitat in Harris and Duteau Creeks has been reduced as a result of the siltation and elimination of shade cover produced by extensive logging.

Excessive deposition of woodburner flyash into creeks from sawmill burners has been a perpetual problem for DFO. Six sawmill burners lie within a 1.5 km radius of Lumby, four of which are in close proximity to Bessette and Duteau Creeks. Photographs and samples taken in 1978 revealed the presence of flyash and sawdust both within the latter two stream channels and along the streambanks below the highwater mark (Canada, DFO, 1978). Flyash and sawdust have accumulated up to 10 cm deep in some locations near the burners. Sawmill burner operation is regulated under Waste Management Branch (WMB) permits which restrict the amount of flyash to be deposited. Recent conversion by some of the operations to more efficient burners has reduced the accumulation, but the quantity of fallout still remains unacceptable (Canada, DFO, 1978).

The WMB permits stipulate routine monitoring of air emissions, but not flyash accumulation adjacent the mills. DFO recommended that a detailed assessment be made of the impact of flyash emissions upon water quality and fishery resources in Bessette and Duteau Creek (Canada, DFO, 1978). No monitoring has been conducted as of January, 1982 (Kurtz, pers. comm.).

(ii) Agriculture

The lower Bessette Creek drainage, in addition to providing important coho spawning and rearing habitat, is ideal for the production of dairy cattle and winter forage crops. Livestock watering in and near these streams has resulted in streambank erosion and nutrient enrichment from manure deposition. Channelization and rip-rapping have been employed to stabilize the stream and prevent erosion of agricultural lands. Land clearing for agricultural purposes beside streambeds has caused sedimentation (Kurtz, pers. comm.).

(iii) Urban Developement

The Municipality of Lumby currently holds a WMB permit allowing the discharge of chlorinated sewage to the Bessette Creek during freshet. DFO and IPSFC have recommended that discharges be declorinated. As evaporation from the treatment plant sewage lagoons has thus far produced no positive discharge into

the creek, chlorination has not been necessary (Canada, DFO, Unpublished pollution files). However, effluent from the treatment lagoons has been observed seeping through the toe of a dyke and entering Bessette Creek. Because of the low Bessette Creek water levels, this seepage could contribute significantly to nutrient loadings in the Bessette system.

(iv) Minimum Flows

Naturally occurring minimum flows in Bessette, Harris and Duteau Creeks are further reduced by irrigation and domestic water demands. Such demands often lower the discharge rate to levels critical for fish, particularly during late summer and early fall when both agricultural and fishery water requirements are greatest.

In 1976, the Provincial Water Rights and Fish and Wildlife Branches, Federal Ministry of Agriculture and DFO prepared an agreement concerning several water licensing procedures specific to the Bessette Creek system. The agreement addresses DFO's concerns regarding minimum flows and provides restrictive clauses in new water withdrawal licences to protect the fishery resource, cancels unused licenses and enforces timing restrictions on periods of diversion (Hamilton, pers. comm.; Anthony, 1975).

Duteau Creek streamflows have been regulated since 1971 by the Headgate Dam 8 km upstream of Lumby. Reduced flows within the watershed have severely affected the fishery resource. In March 1978, several thousand coho salmon and rainbow trout fry died in Duteau Creek as a result of flow control at Headgate Dam. Artificially increased autumnal flows have also caused stranding and freezing of fry the following spring (Canada, DFO, Unpublished fish-kill data). As there are few water-use requirements downstream of Lumby after September, the Vernon Irrigational District (VID), which operates Headgate, may discontinue or substantially alter flow levels in Duteau Creek to satisfy Okanagan Basin requirements.

DFO is presently licensed to withdraw 1000 acre-feet (1.2 million cubic meters) of water from Grizzly Lake to augment flows in Duteau Creek. The VID simultaneously manages storage to meet

both DFO and their own irrigation and domestic water needs. A legal agreement between the VID and DFO concerning operation and maintenance costs has not yet been prepared.

(v) Mining

The Chaput Logging operation (formerly the Alberta Gypsum Ore Concentrating Mill) located one mile downstream of Lumby on Bessette Creek is a potential source of highly toxic effluent. The mill processes silver, lead, zinc and copper and formerly discharged effluent containing heavy metals and cyanide into a tailings impoundment. Mill modifications, including a partial changeover to a physical recovery process and implementation of bulk concentrate recovery, have eliminated cyanide from the recovery circuit and substantially reduced the tailings heavy metal content. Furthermore, under the terms of the WMB permit, the tailings supernatant is to be recycled into the mill without any positive discharge to Bessette creek. DFO has nevertheless expressed concern over the tailings water seepage into Bessette Creek and possible deleterious effects upon salmon resources (Canada, DFO, Unpublished files).

5. Salmon River and Salmon Arm Tributaries (Area 2)

(a) Fishery Resources

(i) Escapements

The Salmon River and Canoe and Tappen Creeks flow directly into the Salmon Arm of Shuswap Lake. Bolean Creek is a tributary of the Salmon River (Figure 5). Together these streams support average annual escapements of 1300 coho, 230 chinook and 160 sockeye (Appendix IIC). The majority of these stocks (96% of coho and 100% of chinook) spawn in the mainstem Salmon River and Bolean Creek.

Historically, large numbers of sockeye, coho and chinook salmon spawned in the Salmon River system. These stocks were severely depleted by immediate and delayed effects of the 1913 Hell's Gate rock slide. Occasional "stray" sockeye from the dominant year Adams River run spawn in the Salmon River where in 1978 an escapement of 430 sockeye was recorded. Native sockeye

stocks were last recorded spawning in the Salmon River in 1925 (IPSFC, 1954). Coho and chinook spawn from the mouth of the Salmon River upstream to the Falkland bridge. Preferred spawning areas occur within the 25 km section extending from Falkland down to Silver Creek. Twelve kilometres upstream of Falkland, the Salmon River flows underground, blocking salmon migration past this point. Coho also spawn in the lower 6 km of Bolean Creek.

Canoe Creek and Tappen Creek support average annual escapements of 26 and 17 coho, respectively, Distribution patterns for spawning and rearing usually coincide, although some instream variation occurs.

(ii) Fishery Resource Utilization

Salmon stocks from Area 2 contribute annual net wholesale values ($1978) of $30,000 and $13,000 to the Canadian and American commercial fisheries, respectively. The stocks also contribute values of $42,000 to the Georgia Strait tidal sport fishery. The Salmon River and Bolean Creek stocks account for 98% of the above values (Table V).

(iii) Salmonid Enhancement

A proposed hatchery site on the Salmon River near Falkland was found inappropriate due to minimum flow, water quality and habitat degradation problems resulting from agricultural and logging activities within the Salmon River watershed (Ginetz, 1979). No further hatchery plans are being developed at present (Steele, pers. comm.).

In 1952 and 1954, IPSFC attempted to re-establish the sockeye run in the Salmon River by transplanting eyed sockeye eggs from the Seymour River (Area 3). A continuing population was not established (IPSFC, Annual Reports), although "stray" sockeye from the Lower Adams River sockeye run may be responsible for the sockeye which spawned in the Salmon River in 1974 and 1978.

(b) Environmental Issues

(i) Forest Harvesting and Wood Conversion

The upper watershed regions of the Salmon River have been logged, but due to the absence of salmon, no formal assessment of the effects on water quality and potential salmon habitat has been conducted. In 1977, however, it was noted that erosion had occurred throughout the stream from logging in the upper watershed (Brown et al, 1979). Downstream effects on water quantity have not been determined.

The upper watersheds of Bolean and Canoe Creeks have also been logged. Effects on salmon spawning areas in the lower reaches of Bolean Creek have not been noted but if logging proceeds in the steeper sections of the watershed, downstream siltation may become a problem.

A sawmill located at Canoe (on Shuswap Lake) is one of the few water dependent mills in the Sub-basin. As the mill is located at the mouth of Canoe Creek, it is vital that log booming and storage grounds do not obstruct upstream migration or beach spawning of adult salmon, and that debris accumulation does not alter water quality such that rearing juvenile salmon are affected.

(ii) Agriculture

Most of the arable land in the Salmon River valley is currently utilized for agricultural purposes. Dairy and beef farming are the chief activities, but potatoes, grain, hay and poultry are also important. Numerous water quality and fish habitat problems have been identified on the Salmon River. Streamside vegetation has been eliminated in many locations to increase available land for planting or livestock access. Frequent instream watering of livestock has resulted in severely eroded streambanks and heavy siltation while nutrient loading has increased due to manure and fertilizer depositions. A study of Salmon River water quality indicated nitrogen and phosphorus concentrations had increased downstream of the farmland (Bryan, 1975). The total phosphorus input from the Salmon River into Shuswap Lake was greater than that from the Salmon Arm sewage treat-

ment plant, even though the sewage discharge contained a higher concentration of biologically available phosphorus (Canada, Dept. of Fisheries and Environment (DFE) and EPS, 1978). These water quality problems may be further aggravated by low flows.

The lower reaches of the Salmon River meander extensively, eroding agricultural land, and necessitating streambed stabilization through channelization and rip-rapping. Both accelerated downstream erosion and the loss of productive, shallow back-water areas utilized by rearing salmonids may occur.

The mouth of the Salmon River spreads over a wide mud flat. Numerous shallow channels cut through the area and in the past, upstream migrant fish have become trapped and died in these blind channels. The problem was eliminated in 1971 when the river established a new channel with adequate streamflows and water levels.

(iii) Urban Development

The Village of Salmon Arm discharges chlorinated domestic sewage into Shuswap Lake near the mouth of the Salmon River. Residual chlorine in the effluent poses a serious threat to migrating juvenile and adult salmon utilizing the streams in Area 2 (particularly in the Salmon River). In 1979 and April 1981, DFO and EPS respectively, recommended that prior to discharge, the effluent be dechlorinated to less than 0.02 mg/l total residual chlorine. In November of 1981, EPS requested, on behalf of DFO, either implementation of measures to disinfect plant effluent without induced toxicity, or, in the event of continued chlorine disinfection, effluent dechlorination (Canada, DFO, Unpublished files). Nutrients from the sewage treatment facility may accelerate algal production in Shuswap Lake. Alternatives for improving the present discharge of chlorinated sewage into Shuswap Lake include nutrient removal or land disposal via spray irrigation.

(iv) Minimum Flows

The naturally occurring minimum flows and elevated water temperatures in Area 2 streams are the source of sole concern.

These low flows cause certain sections of streams to dry up completely in the summer and early fall. Water withdrawal for irrigation and domestic use compounds the problem. Irrigation demands are greatest during low flow periods and also coincide with the upstream migration of adult chinook salmon. Studies of the Salmon River low flow and water temperature conditions were carried out by the IPSFC (1954) and the B.C. Dept. of Environment (1976). Water temperature data also collected by DFO in 1978 and 1979 have been partially analyzed and a report is forthcoming (Hamilton, pers. comm.). In 1980, DFO conducted further studies to determine the rearing distribution and minimum flow requirements for juvenile salmon production in the Salmon River. These studies document the conflicts between fisheries, irrigation, livestock and domestic uses. Effective in 1981, the Water Management Branch has ceased processing water diversion applications for the Salmon River or its tributaries (Kurtz, pers. comm.).

(v) Linear Transportation

The Canadian National Railway line, Highway #97 and the power transmission lines between Glenemma and Falkland follow a section of the Salmon River containing preferred salmon spawning gravels. Materials deposited during spawning or incubation periods could therefore be especially harmful.

5. Shuswap Lake (Area 3)

(a) Fishery Resources

(i) Escapements

Area 3 includes Shuswap Lake and four tributary streams - the Seymour and Anstey Rivers, and Scotch and Hunakwa Creeks (Figure 6). These watercourses support spawning populations of coho, chinook and sockeye salmon. Shuswap Lake provides rearing areas and migration routes for all salmon originating from the South Thompson/Shuswap Sub-basin, excepting Area 5 (the South Thompson and Little Rivers and Little Shuswap Lake).

The rivers and streams of Area 3 support predominantly sockeye salmon, along with very small numbers of coho and chinook. The average annual escapements, excluding Shuswap Lake, are 23,000 sockeye, 110 coho and 5 chinook (Appendix IIC). The lower 5 km of the Seymour River accounts for the bulk of these escapements, yielding average annual figures of 20,000 sockeye and less than 50 coho and chinook salmon (combined total). A maximum escapement of 63,000 sockeye was recorded in the Seymour River in 1978.

Of the remaining spawning streams, Scotch Creek averages 2800 sockeye and less than 50 coho. Unlike the majority of Thompson River Basin sockeye spawning areas which experience peaks in the 1970, 1974 and 1978 cycle years, Scotch Creek's maximum sockeye escapements occur one year earlier (approximately 14,000 spawners were observed in 1977). Sockeye spawning sites are distributed throughout the 12 km of channel between the mouth and the falls. Coho spawning is limited to the lower 2 km.

Sockeye and coho spawning in the Anstey River is restricted to the lower 5km, below an impassable waterfall. Average escapements for the 1969-1978 period are 180 sockeye and 25 coho, with a 1978 sockeye peak of 890 individuals. Hunakwa Creek average annual escapements for sockeye and coho are 180 and 50, respectively, with peaks of 1300 sockeye and 200 coho during 1978 (Brown et al, 1979). No sockeye escapements for Hunakwa Creek appear in Appendix IIC due to its designation by IPSFC as a miscellaneous stream.

In addition to utilizing the above streams, sockeye salmon also spawn on numerous littoral beach areas in Shuswap Lake (Figure 6). Major sites of sockeye salmon beach spawning occur along 25 km of shoreline near the Adams River mouth. During the 1978 dominant year, 62,000 spawners were observed in the vicinity. An additional 38,000 spawning sockeye were enumerated in Seymour, Salmon and Anstey Arms. Beach spawning data are included under "Miscellaneous" in Appendix IIC (IPSFC, Annual Reports, 1969 to 1978).

Shuswap Lake is also important as a rearing area. In 1978, a DFO study was undertaken to determine rearing and migration

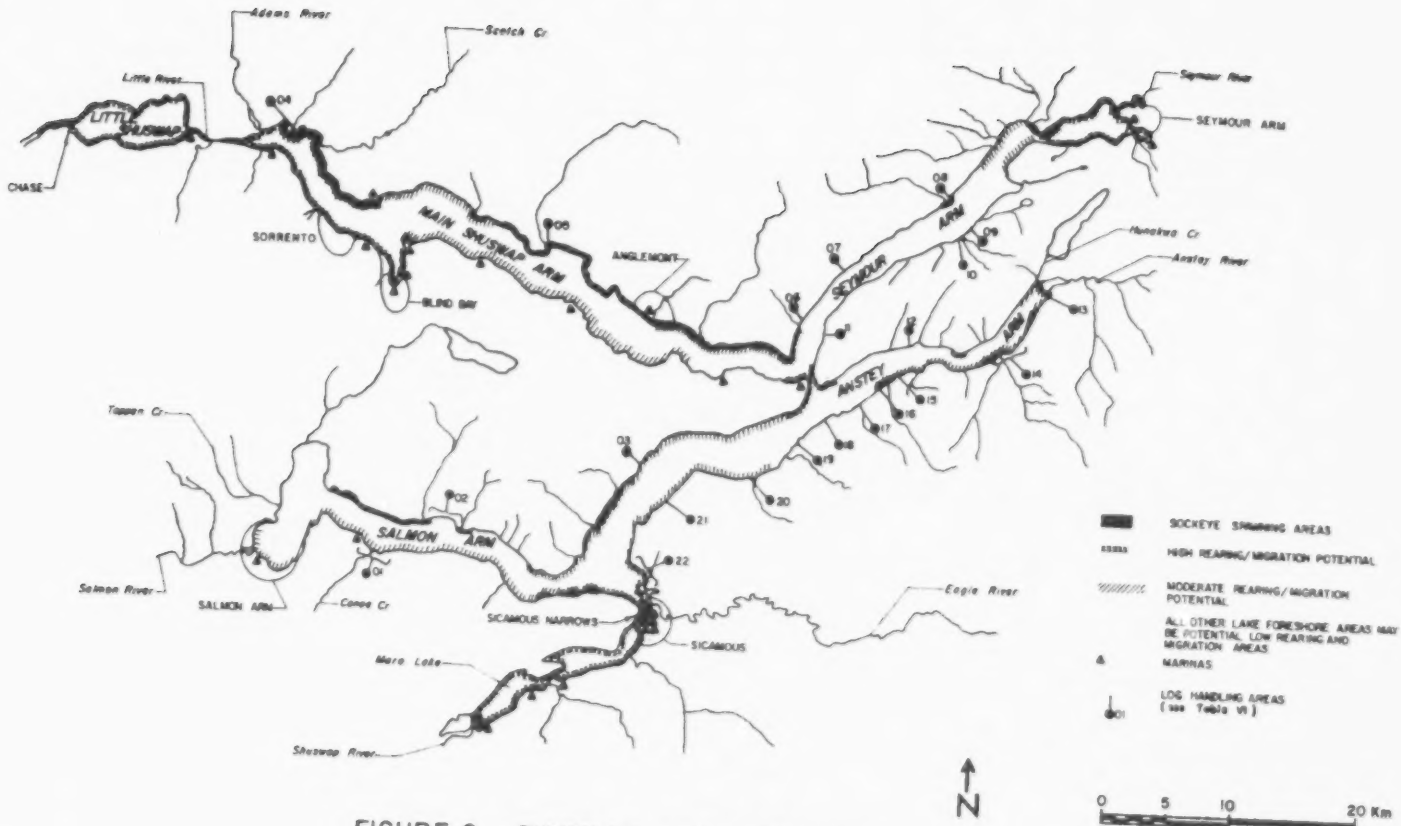

FIGURE 6 - SHUSWAP LAKE SALMON SPAWNING, REARING AND MIGRATORY HABITAT AND LOG HANDLING SITES.

patterns of juvenile salmon in the Shuswap Lake system (Figure 6). The areas identified of primary importance are as follows (Graham and Russell, 1979b):

1. Mara Lake and Sicamous Narrows;
2. The southern shoreline of the Salmon Arm from Salmon River to Sicamous;
3. Foreshore regions on the eastern and western shores of Shuswap Lake from Sicamous to Cinnemousun Narrows;
4. The southwestern shoreline and tip of Anstey Arm;
5. The northern tip of Seymour Arm;
6. All the littoral areas of the Main Shuswap Arm and Little Shuswap Lake (with the exception of a small section of foreshore on the north side of the main Shuswap Arm).

(ii) Fishery Resource Utilization

Estimated annual contributions ($1978) of the Shuswap Lake area to the commercial fisheries of Canada and the USA have been calculated at $470,500 and $316,000, respectively. The Georgia Strait tidal sport fisheries contribution is valued at $2600 (Table V). These figures do not include values for Shuswap Lake beach spawning sockeye. Salmon sport fishing in Shuswap Lake is concentrated near Sicamous Narrows, where lake trolling for upstream Shuswap River migrants occurs, and off the mouth of the Adams River during spawning periods.

(iii) Salmonid Enhancement

Sockeye salmon from Seymour River serve as an important donor stock of eyed sockeye eggs to other streams with enhancement potential. Transplant programs include Upper Adams River and Salmon River. Additional transplantation of Seymour River eggs and construction of an incubation channel were proposed for rehabilitation of Upper Adams River stocks (IPSFC, 1972). Modest hatcheries are possible on the Seymour River and just downstream of Adams Lake. The Adams facility could serve as a source of fish for colonization of the Upper Adams River.

(b) Environmental Issues

(i) Forest Harvesting and Wood Conversion

The upper Seymour River, first logged in the early 1900's, experienced renewed activity in 1973, when further logging road access was constructed (Kurtz, pers. comm.). While there is now no active logging in the Anstey River system, previous operations have left logs and debris throughout the lower 2 km, continuous streambank erosion around the log jams, and considerable streambed scouring, especially during freshet (Brown et al, 1979). The latter problems are of particular concern due to the presence of sockeye and coho spawning sites in the lower river reaches and in adjacent beach areas of Shuswap Lake. Intensive logging affected either flow patterns or the degree of erosion (Brown et al, 1979).

Logging activities on Scotch Creek, on the other hand, have had serious impacts on the aquatic environment. The watershed has been extensively logged leading to an altered flow regime, poor water retention and flash floods which in turn have promoted steambed scouring. Log jams and log debris throughout the lower 2.5 km cause severe erosion, silting, scouring and stream channel changes. Siltation from road construction is also a serious problem.

(ii) Shuswap Lake Log Transportation and Storage

Up to 1978, log handling at twenty-two sites (including ten active sites) had been authorized under Provincial Lands Management Branch Leases (Canada, DFO, 1974-78; Sadler, 1978). The locations of the log handling sites relative to salmon habitat and details regarding the sites' status and use are found on Figure 6 and Table VI, respectively. Log handling sites may degrade foreshore habitat through the accumulation of bark and logging debris, toxic leachate formation and the reduction of dissolved oxygen levels, thereby interfering with lake beach spawning and reducing rearing habitat (Schoumburg, 1970). This is a major concern in Shuswap Lake where beach spawning of sockeye salmon, rearing and migration of sockeye, coho and chinook salmon are critical to salmon production in the Thompson Basin. The lack of information concerning the impacts of log transporta-

tion and storage in the Shuswap Lake Area has prompted DFO to increase surveillance of potential and current problems (Kurtz, pers. comm.).

(iii) Urban and Recreational Development Shuswap Lake

Shoreline development of Shuswap Lake for residential and recreational purposes is proceeding more rapidly compared to other areas in the Thompson Basin. This region has experienced an annual population growth of 6% compared to less than 3% for the Province of British Columbia as a whole (Graham and Russell, 1979b; Harrison, 1977). The demand for subdivision property is greatest where lakeshore access is readily available. The areas of heaviest development include Salmon Arm, Adams River delta foreshore, Blind Bay and Sicamous Narrows, with Seymour River, Anglemont, Sorrento and Scotch Creek experiencing lesser degrees of activity (Figure 6).

Recreational and urban development may contribute significantly to foreshore habitat destruction and general water quality degradation. Although the full impact of lake and foreshore development will likely be experienced in the future, some localized effects have already been observed. For example, it is anticipated that an increasing number of summer cottages (which often develop into permanent residences) will cause gradual degradation of water quality due to nutrient addition from septic fields and hydrocarbons from oils and boat motor fuels. Alienation of salmon spawning and rearing areas by water-based recreational activity (such as swimming and boating) and construction of marinas and wharves are also concerns. These effects have not been documented in detail for the Shuswap Lake region. A 1979 DFO study revealed that construction and initial operation of a marina near the Scotch Creek mouth was not having an appreciable impact on rearing habitat, water quality or sediment chemistry. Long-term impacts of marina operations on Shuswap Lake have not been evaluated (Graham and Russell, 1979a).

TABLE VI
SHUSWAP LAKE LOG HANDLING SITES [1,2]

SITE NUMBER	SITE LOCATION	COMMENTS
01*	Canoe	- log dump and mill foreshore storage area
02*	Heralds Bay	- temporary dumpsite, and also dewatering site for sample bundles from all dumps - important for winter log storage
03*	Tillis Landing	- new dumpsite with small storage area (long-term)
04*	Lee Creek	- dumpsite and storage area used as alternate to Magna Bay (publically controversial)
05	Magna Bay	- former dumpsite relocated to Lee Creek
06*	Cape Horn	- preferred log storage and towing area
07	Woods Landing	- potential storage area
08*	Two Mile	- central log dump area - storage for Upper Shuswap Public Sustained Yield Unit (PSYU) - logging camp location
09	Wright Lake	- proposed dumpsite
10	Wright Lake South	- proposed dumpsite
11	Anstey South	- proposed dump and storage site, could become a central dumping area
12*	Bell Pole	- active dumpsite, critical to logging operations
13	Head of Anstey Arm	- proposed dump and storage site
14	Four Mile	- proposed temporary dumpsite
15	Queest Creek North	- proposed dumpsite
16	Queest Creek South	- proposed temporary dumpsite
17*	McConnel Creek	- active dumpsite
18	Wilson Creek North	- proposed dumpsite
19*	Wilson Creek	- active and operational weighing and dewatering site
20	Marble Point	- proposed dump and storage site
21	Hungry Cove North	- proposed dumpsite
22*	Old Town Bay	- extremely critical booming area to logging operations, and a primary log storage area

[1]See Figure 5 for location of log handling sites relative to fish rearing and migratory habitat
[2]Sadler (1978)
*Active site as of 1978

(iv) Additional Issues

A seasonally operated placer mine on Scotch Creek could lead to erosion due to land clearing activities and heavy silt discharges from the gold extraction process.

Pesticides for mosquito and forest insect control are a potential source of pollution. In 1963, the largest recorded fish kill in B.C. freshwater occurred as a direct result of an incorrectly diluted application of DDT. More than 3 million sockeye and chinook fry died in Shuswap Lake at the Adams River outlet.

6. Adams River System (Area 4)

(a) Fishery Resources

(i) Escapements

The Adams River system incorporates Adams and Tumtum Lakes, Sinmax Creek, Momich River and the Upper and Lower portions of the Adams River. Average salmon escapements to Area 4 watercourses are 600 coho, 1800 chinook, 120 pink and 430,000 sockeye (Appendix IIC and Table V).

The 12 km long Lower Adams River supports an average annual spawning population of 430,000 sockeye, 120 pink, 280 coho and 1800 chinook salmon. These ten year average escapement figures do not reflect peak spawning populations due to the cyclic and dominant year patterns found in the sockeye salmon life cycle. The smallest number of spawning sockeye in the Lower Adams (during the 1969-78 period) was observed in 1976, when 5000 fish were recorded. In contrast, the 1978 dominant year yielded almost 1.5 million fish. The Lower Adams River sockeye run has increased in each dominant year since 1962, when only 500,000 were noted. Juvenile sockeye from this run rear in Shuswap and Little Shuswap Lakes and in the near shore areas of the Adams River mouth (IPSFC, Annual Reports, 1969 to 1978).

The Upper Adams River between Tumtum and Adams Lake (approximately 96 km) sustains average annual escapements of 140 coho and 15 sockeye. Historically, the Upper Adams River salmon

run was thought to rival the present day run in the Lower Adams River. The number of spawners normally reaching the Upper Adams River was drastically reduced by the 1913 Hell's Gate rockslide and the operation of a logging splash dam at the Adams Lake outlet between 1908 and 1945 (Allen, 1979).

Sinmax Creek and Momich River, which both drain into Adams Lake, have average escapements of 130 and 50 coho, respectively. No sockeye utilize Sinmax Creek, but the Momich escapement is 300 fish, with a peak of 2000 observed in 1976. Sockeye progeny from Upper Adams and Momich Rivers are believed to rear in Adams Lake.

(ii) Fishery Resource Utilization

Commercial downstream landings attributable to the Adams River system are valued ($1978) at $8,716,000 (Canada) and $5,819,000 (USA). Adams River stocks taken in the Georgia Strait tidal sport fishery are valued at $131,000. Salmon stocks from the Lower Adams River total 58% of the entire Thompson Basin contribution to the Canadian Commercial fishery (Tables II, V). Area 4 stocks also contribute an estimated 666,000 fish annually to the American commercial fishery. No salmon sport fishing is permitted in the Adams River.

(iii) Salmonid Enhancement

Upper Adams River

Considerable potential for sockeye enhancement has been identified for the Upper Adams River, as it historically supported a large run of sockeye salmon. Adams Lake has potential rearing capacity for progeny of approximately 600,000 spawning sockeye. However, combined escapements to streams tributary to Adams Lake (Momich River, Upper Adams River and Sinmax Creek) have averaged less than 350 fish annually (1969-1978).

Based on available spawning area, the Upper Adams River could support more than 2 million spawning sockeye salmon. The IPSFC has initiated several programs to increase this run. The transplantation of 6.25 million eyed sockeye salmon eggs into the Upper Adams River between 1950 and 1960 failed to enhance escape-

ments (IPSFC, 1972). Transplants of eyed eggs in 1974 also failed to produce significant 1978 returns (IPSFC, 1969 to 1978). Nevertheless, the use of Seymour River stocks to produce a sockeye run to the Upper Adams River may still be feasible through a substantial increase in fry production. The IPSFC is considering using the more promising Momich River stocks for subsequent transplants (Cooper, 1980). An egg incubation channel on the Upper Adams River similar to that on the Upper Pitt River (which has a capacity of 4 million eggs and 3 million fry) could return 22 million eggs to the Upper Adams River in the following cycle year (IPSFC, 1972).

Lower Adams River

In October 1978, the 977 hectare Roderick Haig-Brown Conservation Area was established on the Lower Adams River to preserve and protect sockeye spawning grounds between Adams Lake and Shuswap Lake. A Provincial Government Order-in-Council reserved a 12 km long corridor over private and public lands along the river (Canada, DFO, 1978). During dominant cycle years, over 100,000 visitors (160,000 in 1978) viewed an estimated 1.5 million sockeye spawning within the reserve. Conservation Area designation is an excellent way of reserving a "greenstrip" to protect the multi-million dollar Adams River salmon run. Public exposure to the resource in the Conservation Area through displays and observation of sockeye spawning is an important educational tool in preserving and protecting the salmon resource.

(b) Environmental Issues

(i) Forest Harvesting and Wood Conversion

As early as 1908, impacts from the forest industry have significantly degraded sockeye habitat and reduced sockeye populations in the Area 4 watershed. At that time, the Adams River Lumber Company constructed a logging splash dam at the mouth of Adams Lake to facilitate flushing of logs down the Lower Adams River. As the dam was designed to maintain the lake level equivalent to that at spring freshet, the river would alternate between minimum flows when certain reaches would virtually dry up and maximum flows when the gates were opened to transport logs to Shuswap Lake (Brown et al, 1979). The low flows impaired or

completely prevented adult and juvenile migrations and exposed incubating eggs. The log drives, with their accompanying high flows, often coincided with the normal September spawning period in the Lower Adams. Ultimately, the drastic flow reductions and scouring of spawning beds by logs decimated the Lower Adams run. Recovery of the run only occurred after the timber company ceased logging and sawing operations in 1925 and the splash dam gates were permanently opened (Brown et al, 1979; Allen, 1979).

The presence of the splash dam at the mouth of Adams Lake has also had a profound effect on the Upper Adams River sockeye escapements. Even after the gate opening in 1925, stocks were unable to negotiate the barrier and a small fishway was built into the dam. Unfortunately, this provided only limited passage upstream (Cooper, 1980) and the dam was finally removed in 1945 by the IPSFC with the approval of DFO. The combined effects of the 1913 Hell's Gate rockslide and splash dam operation probably contributed to the reduction of the Upper Adams River run from a level which may have equalled the present Lower Adams run (Allen, 1979).

Five logging companies presently harvest timber in the Upper Adams River watershed. Problems associated with the construction of access roads, land clearing and logging near streams have caused streambank erosion, streambed scouring, siltation and flow fluctuations. While the impacts have not been quantitatively documented, visual appraisals indicate marked degradation of spawning, rearing and migratory habitat.

Logging activity also threatens fishery resources on the Adams Lake tributary streams such as the Momich River and Sinmax Creek. Throughout Sinmax Creek, log debris and fallen trees form potential obstructions to migrating fish (Brown et al, 1979).

There is a sawmill currently in operation near the outlet of Adams Lake. Logs harvested from the upper watersheds surrounding the lake are dumped, transported, stored and sorted in the lake. These activities, especially those beside the sawmill, have resulted in the accumulation of large quantities of bark and debris on the lake bottom. Smaller amounts of debris also move down the Lower Adams River in spite of a 'stiffleg' debris catcher installed at the lake outlet.

(ii) Minimum Flows

The impact of logging on flow regimes in the Adams Lake watershed has not been monitored, although fluctuations have been observed on the upper Adams River. In light of the sockeye enhancement potential of the Adams River system, the possibility of altered flow regimes due to increased logging activity is a source of concern (Brown et al, 1979; Goodman, 1979).

The lower Adams River often exhibits high water levels during the fall spawning period, so that when flows eventually drop in November, the side channels dry up, stranding sockeye and chinook eggs. This ultimately may curtail escapements of returning adults (Brown et al, 1979). In 1974, the IPSFC constructed a rock groin along the left bank near Lower Adams River mouth to equalize left and right channel flows. Previously, low right channel flows exposed incubating salmon eggs (Brown et al, 1979).

(iii) Urban Development

Adams Lake is not as highly developed for urban and recreational purposes as other Sub-basin lakes. Nevertheless, development sites at the mouth of Sinmax Creek (Skwaam Bay) and the Adams Lake outlet (Indian Point) can be expected to grow. Localized water quality degradation may result from septic tank and sewage effluent discharges. In recognition of the role of the Lower Adams River as one of the major sockeye salmon producing rivers in B.C. and the potential for urban development, DFO recently completed a study documenting juvenile salmonid utilization of the foreshore area at the Adams River mouth (Graham and Russell, 1979b). Results indicate extensive use by juvenile chinook of the delta-lake front area. The rearing time roughly coincides with foreshore inundation during high water such that development activities on the foreshore or upland could generate serious impacts on rearing habitat (Graham and Russell, 1979b).

(iv) Agriculture

The effects of agricultural activities on fishery resources are minimal in the Adams River watershed with the exception of

some minor siltation problems which occurred following land clearing along Bear Creek, a tributary to Sinmax Creek. Concern about the potential effects of streambank protection measures for erosion has also been expressed (Aurel, pers. comm.).

(v) Mining

Kamad Silver Mine operates on Homestake Creek, which enters Sinmax Creek above the coho and sockeye spawning grounds. This mine caused heavy siltation and water quality degradation in Sinmax Creek in 1971 (Brown et al, 1979). Although the mine is not currently operating at peak capacity (Voysey, pers. comm.), full production could presumably resume.

7. South Thompson River (Area 5)

(a) Fishery Resources

(i) Escapements

The South Thompson River area contains the South Thompson and Little Rivers and Little Shuswap Lake. Shuswap and Little Shuswap Lakes are connected by the 4 km long Little River. The South Thompson River flows southwest into the Thompson River east of Kamloops Lake (Figure 5). The average annual escapement of salmon to Area 5 watercourses is 44,000 sockeye, 5400 chinook and 330 pinks (Appendix IIC).

For the South Thompson River mainstem, average annual escapements are 5200 chinook and 3200 sockeye salmon. Both chinook and sockeye salmon spawn chiefly at 'Chase Riffles' 3 km below Chase, whereas pink salmon spawn about 1.4 km downstream of Chase. Annual escapements of pink salmon average 110 fish (220 during odd years). The Little River has average annual escapements of 300 chinook, 40,000 sockeye and 220 pink (440 in odd years). In the 1970 dominant cycle year, 170,000 sockeye were counted. Sockeye escapements from Little River represent approximately 5 to 10% of the Adams River dominant year sockeye run.

Sockeye, chinook and pink salmon utilize the spawning areas of the South Thompson River mainstem and Little River. Shuswap

and Little Shuswap Lakes provide rearing habitat for juvenile sockeye and chinook salmon from the Little River run. Four species (sockeye, chinook, coho and pink) migrate through these areas as adults to the South Thompson/Shuswap Sub-basin spawning grounds. Progeny from upstream spawning areas also utilize Area 5 watercourses for migration and rearing during their seaward migration.

(ii) Fishery Resource Utilization

Area 5 salmon stocks contribute net wholesale values ($1978) of $1,138,000 and $641,000 to the Canadian and American commercial fisheries, respectively, and an additional $368,000 in values to the Georgia Strait tidal sport fisheries (Table V) . Salmon sport fisheries exist on the South Thompson, with heavy fishing pressure on chinook salmon downstream of Chase. Chinook fishing closures are in effect from September 25 to October 31 each year. Although there has been a trend more recently for the South Thompson/Shuswap Native people, like their North Thompson counterparts, to fish the Fraser River, an estimated 2500 sockeye and 350 chinook were taken in 1978 in the South Thompson, Little and Shuswap Rivers during the Native food fishery.

(iii) Salmonid Enhancement

Area 5 is included in the enhancement feasibility program for the Thompson River Basin. In 1976 and 1979, juvenile chinook from the South Thompson and Little Rivers were coded-wire tagged to determine their migratory habits and assess rearing distribution and possible enhancement sites (Canada, DFO and Province of B.C., 1977 to 1979; SEP Annual Reports; Buxton, 1976).

(b) Environmental Issues

(i) Forest Harvesting and Wood Conversion

Impacts resulting from the forest industry are not a problem within Area 5. No adverse impacts from the small sawmill on Little River have been observed to date.

(ii) Agriculture

Mixed farming is carried out adjacent to the South Thompson River. As the river banks are gently sloping and relatively stable, erosion has not been a major concern to date (Goodman, 1979). Water withdrawals are not as critical on the South Thompson River as in other regions due to flows ranging from 2200 to 52,000 cfs. Intake structures, however, often pose a problem where they are not properly screened or maintained to prevent fish entrainment. Occasional siltation of spawning grounds due to upstream or within-gravel excavation for water sites has occurred (Goodman, 1979). A proposed feed lot in the Campbell Creek area 9 km east of Kamloops could introduce excessive nutrients into the South Thompson River.

(iii) Urban Development

Several small communities, including Chase, Campbell Creek, Monte Creek and Pritchard, are situated along the Thompson River. The region is a popular vacation area, with many seasonal residences adjacent the rivers and lakes. Little River is bordered both by an Indian reserve as well as other residences along the greater part of its length and therefore further development is not anticipated in the foreseeable future (Aurel, pers. comm.).

(iv) Additional Concerns

Dredging for large vessel passage has been proposed for Little River, Chase Rapids and other parts of the South Thompson River system. Salmon spawning, incubation and rearing both within the dredged area and downstream could be affected by direct destruction of habitat, water quality alterations or physical changes (eg. siltation) if the proposal is implemented (Forty, pers. comm.).

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APPENDIX I
EFFECTS OF THOMPSON RIVER BASIN ACTIVITIES ON SALMON RESOURCES

Part II of this report identified the conflicts between the salmon fishery resource and various land and water use activities for the drainages, streams or lakes of the Thompson River Basin. This Appendix summarizes the effects of the land and water uses found in the Thompson River Basin on salmon habitat and water quality.

A. FOREST HARVESTING AND WOOD CONVERSION

1. Forest Harvesting

(a) General Impacts

Forest management and harvesting practices directly affect the hydrological cycle of watersheds and hence the aquatic environment. Removal of the forest canopy, cutting patterns, rate of cut, road building, log transportation and log handling may have adverse affects on stream hydrology, water quality and invertebrate and fish communities.

Partial or complete removal of forest cover bordering stream channels may increase water temperatures beyond the range tolerable to salmon populations (Ringler and Hall, 1975). Removal of the canopy and supporting root systems as well as disruption of forest floor and understory vegetation may increase soil moisture saturation and soil instability, permitting erosion and debris accummulation, particularly during periods of heavy precipitation (Toews and Brownlee, 1978). Destruction of the forest cover may also result in higher peak flows during the spring freshet and fall wet periods and produce an overall increase in the annual stream flow. The latter increase in turn may result in abnormal sediment loads in streams during storm events due to bank scouring, bedload movement and channel alteration. Finally, normal stream productivity may be influenced through altered nutrient input and the reduction of

terrestrial insect populations normally associated with streamside vegetation (Chapman, 1962).

The accumulation of logging debris in small streams or lakes can reduce salmon production by altering pool to riffle ratios and destroying salmon eggs incubating within the gravel. Decaying organic debris deposited in streams increases the biochemical oxygen demand, reducing the dissolved oxygen available in both surface and intragravel waters (Triska and Sedell, 1975). Furthermore, logging debris in streams can interfere with salmon fry emergence from spawning gravels (Chapman, 1962; Gordon and Martens, 1969). Studies have indicated that water-soluble extractives or leachates from logging debris may be highly toxic to salmon fry (Peters et al, 1976).

All the above effects may be further augmented by access roads subjected to compaction, siltation and overland water flow. Improper road building techniques may initiate or accelerate mass soil movements such as debris avalanches and soil slumps. Cleared landings, skid trails and tractor access may also promote surface flows, further accelerating both erosion and soil movement and leading to sediment and debris deposition in watercourses.

(b) Effects of Increased Sedimentation

Excessive levels of suspended solids may directly affect adult and juvenile fish by causing body abrasion and gill tissue damage. Gill lamellae may become clogged with silt, reducing the gas exchange efficiency. Lesser concentrations of suspended solids may cause physiological stress (Cordone and Kelley, 1961), render fish more susceptible to disease, predation and the deleterious effects of pollutants and reduce the ability of fish to swim and feed.

Sedimentation in spawning grounds destroys eggs, alevin and emergent fry by altering physical (e.g. temperature, gravel poro-

sity, water percolation) and chemical (e.g. pH, dissolved oxygen) parameters essential to egg and juvenile salmon development (Cordone and Kelley, 1961; Ritchie, 1972). In addition to modifying the stream profile, increased sedimentation may reduce availability of rearing habitat.

Excessive loads of suspended solids may cause normally clear waters to become turbid, reducing light penetration and therefore the photosynthetic activity of phytoplankton, periphyton and macrophyte communities. This reduced primary productivity precipitates reductions in secondary productivity. If turbid conditions persist, effects on stream invertebrate and fish populations may be long term (Cairns, 1968; O'Connor et al, 1977).

The deposition of large amounts of organic and inorganic material may blanket streambeds and lake beach areas, smothering aquatic plants and benthic invertebrate communities. In addition, fine particles may fill the gravel interstices which provide habitat for invertebrates (Gordon and Martens, 1969; Langer, 1974).

(c) Log Dumping, Sorting, Storage and Lake Transportation

Physical effects of log dumping, sorting, storage and transportation in lakes include the settling of debris (e.g. wood fragments and sunken logs) and disturbance of the substrate from logs striking the bottom during dumping operations. Log booms frequently reduce wave action, allowing suspended material to settle and fill gravel interstices. Benthic algae and sedentary invertebrate populations may be smothered and available benthic habitat and littoral rearing and spawning areas may be eliminated.

Certain compounds leached from wood debris (e.g. tannins, resin acids, lignins) are highly toxic to fish (Gordon and

Martens, 1969; CPAR, 1977). A significant oxygen demand may occur in interstitial and overlying waters as a result of bark decomposition. Hydrogen sulphide released during this decomposition may be toxic to fish and other aquatic organisms (Servizi et al, 1969; Smith et al, 1976; Broderius and Smith, 1976).

The combined physical and chemical impacts of log handlng activities may seriously affect biotic communities. The loss of habitat, presence of toxic chemicals and depressed dissolved oxygen levels may critically reduce the aquatic plant, invertebrate and salmon populations. This is particularly true when the shoreline utilized comprises a significant proportion of the available littoral area.

2. Wood Conversion
   (a) Sawmills

In the primary wood products industry, approximately 50 percent of the delivered log volume emerges as waste from sawmills (Evans, 1973). Although traditionally this waste was incinerated in beehive burners, the current practice is to recover a large amount of this waste. However, sawdust, shavings and other fine wood residues are often stock-piled or "hogged" in a hammer mill to yield hogfuel, which is generally used for landfill material, creating two major environmental problems:

1. The physical loss of valuable littoral habitat (and its associated flora and fauna) through the deposition of hogfuel on foreshore areas or adjacent to streams.

2. The formation of toxic leachates from hogfuel in stockpiles or land-fills (Corder et al, 1972). As hogfuel is often used to fill low-lying areas, (e.g. regions with a high water table) or lake foreshore areas, the leaching process may continue over a number of years. The residue from hogfuel used in steam-plant burners, is water soluble

and the unneutralized leachate from this residue, which is often deposited in landfills, is also toxic (Evans, 1973).

(b) Pulpmills

British Columbia pulpmills discharge large volumes of effluent containing a complex array of organic and inorganic compounds. Major environmental concerns arising from pulpmill discharges are related to the concentration of suspended solids, biochemical oxygen demand, discolouration, toxicity of the effluent and nutrient enrichment.

General problems associated with suspended solids are discussed in Section 1a(ii) of this Appendix. More specifically, certain suspended wood fibres are toxic to fish (Poole, Wildish and Kristmanson, 1978), and the simultaneous presence of organic solids and dissolved organic compounds may seriously deplete dissolved oxygen levels in the receiving waters.

The discolouration of waters receiving pulpmill discharges may be aesthetically unsatisfactory and can reduce light penetration and impair primary production. Discolouration may also interfere with the feeding, predator avoidance and the general behaviour of some invertebrates and fish.

The toxicity of pulpmill effluent varies considerably depending upon the nature of the pulping process, the wood species utilized and the effluent treatment process. Examples of toxic constituents of pulpmill effluent which have been identified include resin acids, chlorinated lignins, phenolics, unsaturated fatty acids and lignin degradation products (Walden, 1976). Pulpmill effluent may have sublethal effects upon organisms (e.g. impaired growth and development), affect behavioural responses (e.g. preference and avoidance reactions) and be acutely toxic (McLeay and Brown, 1979).

In addition to the above concerns, pulpmill effluent discharges may contribute excessive nutrient loads to receiving waters. Recent work by Bothwell and Daley (1981) has revealed that lower Thompson River phosphorus concentrations (at the Kamloops Lake outlet) were higher in late winter and early spring than those in the North and South Thompson and that these higher concentrations were responsible for the nuisance benthic algal growths observed in winter. It was also concluded that the increased phosphorous loadings are the result of point-source phosphorus inputs from the Weyerhaeuser pulp mill and Kamloops City sewage treatment plant.

3. Forest Chemical Applications

Large scale insecticide applications to control forest insects can result in fish kills if proper precautionary measures are not taken to protect waterbodies in the treated areas. Furthermore, pesticide deposition on or near watercourses may lower terrestial insect abundance. The resulting decrease in aquatic insect larvae availability may affect the physical condition, growth and survival of fish (Woodward, 1979).

Herbicides used as conifer release agents in forest silviculture are highly toxic to fish and invertebrate fauna. Although applications are not permitted within the wetted perimeter of lakes, streams, swamps and marshes, the possibility exists for contamination of salmon-bearing waters, especially during aerial application of the pesticide.

B. WATER DIVERSIONS AND HYDROELECTRIC DEVELOPMENT

The modification of watercourses (e.g. diversions, excessive water withdrawal, damming) for irrigation, domestic water supply, hydro-electric power and other purposes may critically affect fish productivity through the reduction of stream flows, fish mortality in water intakes, stranding of fish in irrigation ditches and obstructions to migration (Canada, DOE, 1971).

1. Effects of Water Diversion and Withdrawal

The effects on stream flows elicited by a water diversion will vary according to the volumes of both the diversion and the original stream. Generally, diminished flows are most critical during the normal low flows of late summer or early fall. This is especially true during years of low precipitation, when even small diversions may be detrimental. Decreased warm weather flows may elevate water temperatures and physiologically stress fish, resulting in increased vulnerability to disease and predation, or direct mortalities. Reduced flows also lessen the effective dilution and dispersal of pollutants. Low winter flows may expose and subsequently freeze fish eggs due to insufficient water depth and lack of percolation through the gravel substrate.

In addition to reducing stream flow, water diversions may entrain and destroy large numbers of fish unless adequate screening is provided. Dams and other structures associated with diversion works may also obstruct migrating fish.

2. Effects of Hydroelectric Dams

Hydroelectric installations probably provide the greatest obstacles to migrating adult and juvenile salmonids. Installation of such facilities often decreases peak discharges, increases the height of minimum flows or causes rapid short-term fluctuations in river flow. This in turn influences stream temperature regimes, water flow and gravel composition in spawning areas. Water quality alterations may affect anadromous stocks both in the river and in the reservoir behind the dam. The physical presence of a dam completely blocks upstream migration of adult salmon unless facilities for fish passage are installed. Passage facilities can nevertheless delay migration and decrease the overall rate of survival (Canada, DOE, 1974).

C. AGRICULTURE AND LIVESTOCK WATERING

Agricultural activity within the Thompson River Basin is oriented toward the production of beef and dairy cattle and livestock feed crops such as alfalfa and hay. Impacts on stream water quality, water quantity, biology and channel integrity may occur as a result of channel stabilization procedures, disturbance of riparian vegetation, introduction of deleterious substances in surface runoff and water withdrawals for irrigation or land reclamation.

1. Effects of Irrigation Water Withdrawals

Summer and early fall are the critical periods for rearing juvenile salmonids as demands for irrigation water are high and natural water levels are low. A further reduction in water levels at this time may increase water temperatures, reducing dissolved oxygen solubility and therefore the availability of oxygen to juvenile fish. Reduced water volumes also lessen the dilution of introduced nutrients and contaminants. Water extraction decreases the wetted perimeter surrounding lakes and streams, forcing rearing juveniles into less desirable habitt where they may be subjected to higher water temperatures, increased predation, diminished food sources and greater competition.

Dams constructed for storage of irrigation water may physically obstruct upstream adult or downstream juvenile migration. Reduced or fluctuating downstream flows produced by controlled water release from agricultural impoundments may restrict migration, strand fry and expose incubating eggs to drying or freezing conditions.

The drainage or landfilling of ponds, marshes or swamp lands to increase available agricultural acreage may eliminate the buffering effect exhibited by water bodies during periods of heavy precipitation. The normal gradual release of stored water from such reservoirs permits a more constant flow for rearing juveniles during period of natural low flow. Ditching and

draining of such rearing areas may aggravate the low flow problem during summer months and reduce productive fish habitat (Gram, 1979).

2. Disturbance of Streamside Vegetation

The natural vegetation bordering fish-bearing watercourses is occasionally removed to facilitate livestock watering, to permit access to adjacent fields, to increase available field area and to control floods and erosion (via channelization and rip-rapping). Possible repercussions upon fish habitat include the loss of shade cover, increased summer water temperatures, decreased dissolved oxygen levels, reduced fish food availability (e.g. insects which are associated with the vegetation), reduced streambank stability (Gram, 1979) and increased sedimentation.

3. Activities Influencing Water Quality

While stream water quality may be affected to a minor extent by the activities outlined above, pesticides and organic materials introduced from drainage ditches and feedlots have the capacity to exert more pronounced alterations.

(a) Pesticides

The use of pesticides (herbicides, insecticides, fungicides) is widespread in agriculture and is considered an essential tool for the economical and efficient production of food. At present, little data exist on the quantity of chemicals transported into the aquatic environment via agricultural runoff. Farmers may use only those pesticides registered for agricultural purposes under the Federal Pesticide Products Control Act. However, because the Provincial Pesticide Control Act does not require farmers to obtain permits for pesticide application, the treatments are excluded from any referral and review process.

The impact of pesticide residues in land drainage waters is

complex. Pesticide concentrations in such waters are often unique for a given chemical and depend on the rate of application, geography of the field site, chemical formulations of the particular pesticide (Wauchope, 1978), and other parameters such as weather and precipitation.

While the toxicity (i.e., the concentration of a pesticide which kills a specific organism) of a particular pesticide may be documented, information regarding pesticide effectiveness, persistance, bioaccumulation and sub-lethal effects to non-target organisms such as fish and invertebrates is not available for many chemicals currently in use. Widely used pesticides which are both highly toxic and persistent in the environment pose a hazard to non-target species when large amounts of the chemical are transported in runoff from treated fields to fish-bearing watercourses.

(b) Organic Wastes

Agricultural and livestock waste products (e.g. liquid manure, urine, silage leachate) often exert harmful effects when discharged into the aquatic environment. The extensive use of both natural and commercial fertilizers contributes significantly to the nutrient enrichment of receiving waters, and enhances algae and macrophyte production (Brink, 1975; Kilkus, LaPierrier and Bachmann, 1975). Excessive growths of these flora may smother benthic invertebrate communities and their habitat. Subsequent decomposition of these flora increases the biochemical oxygen demand, reducing the dissolved oxygen available to developing eggs and fry. Salmonid larvae and mature eggs require a somewhat higher degree of oxygen saturation in comparison to other teleosts.

Feedlot "runoff" is generally characterized by elevated nutrient, organic and solids levels which can degrade water quality and ultimately stimulate phytoplankton and macrophyte production. High nutrient and organic loading can lead to

increased bacterial decomposition, a high biochemical oxygen demand and therefore lowered dissolved oxygen concentrations. Fish kills have occurred following the introduction of feedlot wastes into streams (Duffer et al, 1971; Canada, DFO, Unpublished pollution files). Conditions are especially critical during the summer and fall when high water temperatures and low flows are combined with naturally occurring low dissolved oxygen levels.

4. Erosion and Flood Control

Stream channel control is often carried out on agricultural lands in an effort to preserve productive farmland and prevent flooding. Such measures may have harmful effects ranging from the removal of streamside vegetation (see Section 3(b) of this Appendix) to physical modification of the streambed and stream banks (producing siltation and substrate changes).

D. URBAN AND RECREATIONAL DEVELOPMENT

Within the urban or recreational environment, modifications may be imposed on the stream ecosystem by land use activities adjacent to or within water bodies. The following discussion describes the mechanisms by which selected activities may cause physical disturbances, flow regime disruptions and changes in water quality. It is important to keep in mind that while specific examples are examined, they rarely occur in isolation.

1. Physical Disturbance

Land clearing for urban or recreational projects often involves the removal of streamside vegetation with heavy machinery. Such vegetation is essential for providing shelter and shade for rearing juvenile salmonids, providing a source of food (e.g. terrestrial insects) and supporting a root mass which stabilizes streambanks and adjacent soils thereby preventing erosion and subsequent sedimentation (Canada, DFO, 1978).

The construction and maintenance dredging of wharves and marinas may disturb foreshore areas and associated biological communities, reducing the habitat and food sources of salmonid fry. Industrial effluents containing a high proportion of solid materials may settle out on bottom substrates, smothering periphyton and benthic invertebrate communities. Water-based recreational activities such as water skiing, swimming and boating may cause further physical disturbance of fish and fish habitat (Graham and Russell, 1979b).

2. Disruption of Natural Flow Regime

Land clearing activities within a forested watershed may unfavourably transform the natural streamflow regimes. The common practice of clearing extensive tracts of land of all vegetative cover and exposing the soil allows rainfall normally retained within the vegetation to flow more readily and rapidly into adjacent streams. Flood flows occur more frequently, particularly during storm events, causing streambed and bank erosion. As a result, spawning and rearing habitat may be lost and incubating eggs and rearing fish may be displaced or killed.

Flood flow conditions of greater frequency and severity typically occur in urbanized areas and necessitate extensive protective measures such as dykes, erosion control, channel alteration and the installation of oversized culverts to accommodate the high peak flows. The installation of storm sewers and the establishment of increasingly impervious surfaces (e.g. pavement) seriously aggravate the flooding situation. Almost 100 percent of the rainfall onto areas such as pavement is quickly collected and transported by storm sewers to the nearest watercourse, elevating both peak flows and the total annual flow (Canada, DFO, 1978).

3. Degradation of Water Quality

Although substances from urban and recreational development capable of degrading water quality are derived from a wide

variety of sources, the majority enter the aquatic system by way of surface or subsurface "runoff", industrial discharges and domestic sewage effluents.

(a) Industrial Effluents

Industrial effluents can consist of a variety of both industrially produced substances such as heavy and trace metals, PCB's, hydrocarbons, phenols, pesticides and organic compounds, and naturally occurring substances such as leachates from wood debris (tannins and lignins). Either class of substances may affect abundance, distribution, behaviour and physiology of aquatic organisms directly through lethal and sublethal affects or indirectly by altering dissolved oxygen content, turbidity or other parameters. Occasionally, a single pollutant (such as pulp mill effluent) may have both a toxic action and a high oxygen demand. Alternately, two or more toxins present simultaneously may exhibit a synergistic effect whereby the resultant toxicity is greater than the sum of the toxins acting separately.

The discharge of heated waste or process waters may modify the temperature regime of a watercourse both at the discharge site and further downstream. As biological organisms generally function within fairly well defined physiological tolerance limits, an influx of warmer water may result in the elimination of those organisms from that habitat through direct mortalities or migration from the area.

(b) Land "Runoff"

"Runoff" is introduced into the aquatic environment as either surface or groundwater flows, and may carry with it a multitude of potentially deleterious materials depending on the source, including trace and heavy metals, organic materials and debris, nutrients, hydrocarbons and total, suspended and dissolved solids.

Within more developed residential or industrial areas, surface flows originate mainly from storm sewers, whereas in the less urbanized or partially developed zones, flows may be unconfined or follow natural drainage channels. While the characteristics of runoff from undeveloped areas may approximate natural conditions, those from developed or developing districts may contain trace and heavy metals, hydrocarbons, pesticides or toxic materials and may exert direct lethal or sublethal effects (see previous section) or indirect effects on dissolved oxygen, pH and turbidity. Increased turbidity limits light transmission, reducing primary productivity and ultimately aquatic invertebrate abundance.

"Runoff" from cleared land may rapidly erode unstable soil, collecting and transporting large quantities of suspended sediment or silt to adjacent streams. Combined with increased sedimentation from instream erosion, fine sands and silt from exposed earth may cause mortalities of rearing juveniles,spawning adults and incubating eggs within the gravel substrate. In developed urban areas, surface flow volumes greatly exceed groundwater flow and during rainy periods, may even exceed the volume of domestic sewage being discharged from urban areas.

(c) Domestic Sewage

Sewage effluent may enter the aquatic system through point discharges (which may be treated or untreated) to surface water or via septic field discharges to groundwater. The former are common within the urban centers in the Kamloops vicinity while the latter predominate in the smaller communities or settlements. The effect of a sewage discharge on water quality and salmon habitat is related to effluent composition and quantity as well as receiving water flow, temperature and dissolved oxygen concentration. Degradation of receiving waters is most commonly associated with the introduction of organic materials, nutrients (nitrates, ammonia, phosphates), metals, anionic surfactants, phenols and residual chlorines.

Organic material from both point discharges and septic fields is subject to aerobic bacterial decomposition which can deplete the available dissolved oxygen. Diminished oxygen levels will have various effects on fish and invertebrates, depending on each species' physiological tolerance and the extent of dilution. Nutrient enrichment by phosphates, nitrates and micronutrients from sewage may stimulate primary productivity, which in turn stimulates secondary production and fish food availability. Under conditions of excessive nutrient loading, algal production will increase rapidly and then fall off, resulting in a die-off. The subsequent decomposition may then reduce dissolved oxygen levels. Sewage may be directly toxic to both salmon and benthic invertebrates if sufficient concentrations of metals, residual chlorine, phenols or surfactants are present.

E. LINEAR TRANSPORTATION

The linear transportation routes such as highways, railways, pipelines and transmission lines located throughout the Thompson River Basin may impact on fish habitat and water quality.

Highways and railways both involve construction of a continuous roadbed requiring extensive cutting and filling and once in operation, are subjected to vehicular traffic on a fairly regular basis. Although pipeline and transmission line construction requires some vegetation clearing, only minimal ground disturbance is necessary.

Short term impacts usually occur during route construction and include siltation or disturbance of spawning and rearing habitat due to stream crossings or deposition of fill materials; restriction of access resulting from velocity barriers, obstructions and temporary diversions; and spills of deleterious materials such as oils, greases and fuels. During operational phases, potential short term impacts include siltation due to

erosion and deleterious materials deposition (including pesticides for vegetation control).

The more long term effects of linear development result from the permanent changes associated with right-of-way construction, i.e., reduction of streamside vegetation at crossings, the creation of velocity barriers (at bridges, culverts, etc), runoff containing harmful substances (eg. from highways and railways), modification of flow regimes, and siltation due to erosion. The increased access opens up previously undisturbed areas for further development and increases fishing pressures.

APPENDIX IIA: ESTIMATED ANNUAL SALMON ESCAPEMENTS TO THE THOMPSON SUB-BASIN[2]

Thompson Sub-Basin	Stream	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	Avg. 1969-1978
COHO	Thompson River	200	250	200	150	200	250	150	200	N/R	N/R	200
	Bonaparte River	50	25	20	15	10	10	10	20	N/R	N/R	15
	Deadman River	25	50	50	25	100	50	25	35	50	100	50
	Sub-Basin Total[3]	275	325	270	190	310	310	185	255	50	100	265
CHINOOK	Thompson River	2,500	2,500	2,500	2,000	2,000	2,000	4,000	2,000	N/R	N/R	2,440
	Bonaparte River	20	20	20	10	150	25	100	30	N/R	50	45
	Deadman River	25	25	25	10	200	100	250	20	200	280*	114
	Sub-Basin Total[3]	2,545	2,545	2,545	2,020	2,350	2,125	4,350	2,050	200	330	2,599
PINK[1] [2]	Thompson River	240,000	0	250,000	0	230,000	0	350,000	0	970,000	0	204,000
	Bonaparte River	500	0	250	0	500	0	500	0	30	0	180
	Deadman River	N/O	0	25	0	N/O	0	500	0	50	0	58
	Sub-Basin Total[3]	240,500	0	250,275	0	230,500	0	351,000	0	970,080	0	204,270

*70% Jacks.
N/R No Records available (not included in calculation of average).
N/O No fish observed (included in calculation of average).
(1) Pink salmon in the Thompson River System spawn only in the odd years.
(2) Brown, Musgrave and Marshall (1979), coho and chinook; IPSFC (1969-78) pink and sockeye.
(3) Yearly totals do not place values on "P" or "N/R" and may, therefore, underestimate overall escapements. Sub-basin ten-year averages are based on the sum of individual stream ten-year averages.

APPENDIX IIB: ESTIMATED ANNUAL SALMON ESCAPEMENTS TO THE NORTH THOMPSON SUB-BASIN

North Thompson Sub-Basin	Stream	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	Avg. 1969-1978
COHO[3]												
AREA 1	North Thompson River*	P	P	P	200	P	2,000	P	P	1,500	300	1,000
	Louis Creek	1,500	1,500	3,327	2,500	700	3,500	1,500	1,500	2,200	1,300	1,953
	Barriere River	750	750	463	400	350	750	400	300	420	400	557
	E. Barriere River	(1)	(1)	191	75	65	25	75	25	18	110	(1)
	Fennell Creek	200	1,500	432	750	120	200	75	75	380	300	400
	Mann Creek	25	75	143	25	90	25	25	25	60	20	50
	Dunn Creek	(2)	750	310	367	500	300	200	400	530	700	
	McTaggart Creek	(2)	75	32	65	25	25	25	25	75	80	468
	Joseph Creek	200				- Records Discontinued -						
	Lemieux Creek	1,500	1,500	1,500	400	725	750	200	200	650	600	800
	Area 1 Total[5]	4,175	6,150	6,398	4,782	2,575	7,575	2,500	2,550	5,833	3,810	5,228
AREA 2	Brookfield Creek	25	25	2	25	N/O	N/O	N/O	N/O	N/O	N/O	7
	Clearwater Creek	N/R	P	P	P	2,000	2,000	P	P	1,500	400	1,500
	Mahood River	N/R	P	N/R	N/R	N/R	25	25	N/R	10	12	20
	Rea Christie Creek	25	25	17	25	30	N/O	N/O	50	4	20	20
	Mad River					- Records Discontinued -						
	Tumtum Creek	75	N/O	42	30	65	25	25	N/O	10	10	28
	Finn Creek	400	200	179	25	50	75	25	25	6	100	110
	Lion Creek	1,500	1,500	1,810	650	2,250	750	400	750	650	2,300	1,240
	Blue River	N/R	N/R	N/R	N/R	P	200	200	25	510	600	310
	Albreda River	N/R	N/R	N/R	N/R	N/R	25	N/O	N/O	440	180	129
	Raft River	750	750	750	550	450	750	400	400	350	250	540
	Area 2 Total[5]	2,775	2,475	2,800	1,305	4,845	3,850	1,075	1,250	3,480	3,872	3,904
	Sub-Basin Total[5]	6,590	8,625	9,198	6,087	7,320	11,425	3,575	3,800	9,313	7,682	9,132

APPENDIX IIB: (CONT'D.)

North Thompson Sub-Basin	Stream	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	Avg. 1969-1978
CHINOOK[3]												
AREA 1	North Thompson River*	1,500	1,500	1,000	1,500	1,000	1,000	750	3,500	2,250	2,500	1,650
	Louis Creek	25	25	200	200	50	25	75	200	60	75	94
	Barriere River	50	25	10	25	N/R	25	25	75	10	25	30
	Lemieux Creek	N/R	N/R	N/R	25	N/R	N/R	N/R	25	N/R	N/R	25
	Area 1 Total[5]	1,575	1,550	1,210	1,750	1,050	1,050	850	4,000	2,320	3,000	1,799
AREA 2	Clearwater River	1,500	1,500	1,500	1,500	1,500	1,200	1,500	1,500	2,500	3,000	1,720
	Mahood River	N/R	200	136	109	400	200	200	200	425	450	260
	Finn Creek	750	750	750	400	373	750	400	400	525	700	580
	Lion Creek	25	N/O	25	25	N/R	N/R	N/R	25	N/R	30	26
	Raft River	200	75	200	200	200	200	200	200	230	200	190
	Area 2 Total[5]	2,475	2,525	2,611	2,234	2,473	2,350	2,300	2,325	3,680	4,380	2,776
	Sub-Basin Total[5]	3,050	4,075	3,821	3,984	3,523	3,400	3,150	6,325	6,000	7,380	4,575
SOCKEYE[4]												
AREA 1	North Thompson River	N/O	270	888	465	N/O	343	123	580	1,372	N/O	362
	Barriere River	40	2	5	94	22	4	N/O	85	18	N/O	27
	Fennell Creek	52	N/O	1,300	1,931	285	N/O	4,127	4,090	355	675	1,308
	Area 1 Total[5]	92	272	2,193	2,490	227	347	4,250	4,675	1,743	675	1,697
AREA 2	Raft River	5,593	4,474	840	11,151	2,729	2,396	2,664	8,684	648	2,500	4,168
	Area 2 Total[5]	5,593	4,474	840	11,151	2,729	2,396	2,664	8,684	648	2,500	4,168
	Sub-Basin Total[5]	5,685	4,746	3,033	13,641	2,956	2,743	6,914	13,359	2,391	3,175	5,865
PINK[4]	North Thompson River*	N/R	0	N/R	0	N/R	0	N/R	0	150[6]	0	150[6]
	Sub-Basin Total[5]	N/R	0	N/R	0	N/R	0	N/R	0	150[6]	0	150[6]

* Coho, chinook, pink spawning occurs throughout but mainly in Area 1.
P Salmon present but not enumerated (not included in calculation of average).
N/O Stream inspected but no fish observed (included in calculation of average).
N/R No records available (not included in calculation of average).
(1) Includes Barriere Creek
(2) Includes Joseph Creek.
(3) Brown et al. (1979).
(4) IPSFC (Annual Reports). Pink salmon from the Thompson River system spawn in odd years only.
(5) Yearly totals do not place values on "P" or "N/R" and may, therefore, underestimate overall escapements. Sub-basin ten-year averages are based on the sum of individual stream ten-year averages.
(6) Pink salmon were first observed in the North Thompson River in 1977.

APPENDIX IIC: ESTIMATED ANNUAL SALMON ESCAPEMENTS TO THE SOUTH THOMPSON/SHUSWAP SUB-BASIN

South Thompson/ Shuswap Sub-Basin	Stream	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	Avg. 1969-1978
COHO[5]												
AREA 1	(a) Eagle River	750	1,500	1,500	1,500	1,500	3,500	1,500	1,100	2,694	2,000	1,754
	South Pass Creek	(1)	--	--	--	--	--	--	20	40	50	
	(b) Blurton Creek	(2)	--	--	--	--	--	--	25	40	10	244
	Shuswap River (Lower)	750	400	75	300	200	100	100	40	100	300	
	Shuswap River (Middle)	750	400	400	400	400	500	200	60	594	350	400
	Wap Creek	N/O	400	25	200	200	25	200	20	516	300	187
	(c) Bessette Creek	1,500	750	750	2,000	750	1,500	750	25	70	N/O	
	Duteau Creek	(3)	--	--	--	--	--	--	325	94	400	924
	Creighton Creek	(3)	--	--	--	--	--	--	40	2	30	
	Harris Creek	(3)	--	--	--	--	--	--	105	N/O	150	
	Area 1 Total[10]	3,750	3,450	2,750	4,400	3,050	5,625	2,750	1,760	4,150	3,890	3,509
AREA 2	Canoe Creek	N/O	25	25	25	25	25	25	10	N/O	100	26
	Tappen Creek	25	25	25	25	25	N/O	25	1	12	2	17
	Bolean Creek	(4)	--	--	--	--	--	--	50	N/O	50	1,284
	Salmon River	1,500	750	1,500	2,000	750	1,500	750	900	1,588	1,500	
	Area 2 Total[10]	1,525	800	1,500	2,050	800	1,525	800	961	1,600	1,522	1,327
AREA 3	Seymour River	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/O	25	N/O	13
	Anstey River	25	25	N/O	25	25	25	25	25	N/O	75	25
	Nunakwa Creek	75	25	25	25	75	75	25	25	N/O	200	50
	Scotch Creek	N/O	200	25	25	25	25	25	5	N/O	N/O	25
	Area 3 Total[10]	100	250	50	75	125	125	75	55	25	275	113
AREA 4	Lower Adams River	750	400	300	200	300	200	100	10	338	150	275
	Simaa Creek	200	200	213	104	165	200	75	25	40	55	130
	Momich River	200	N/O	75	25	25	25	25	N/O	20	40	44
	Upper Adams River	P	P	P	P	P	200	75	P	150	P	140
	Area 4 Total[10]	1,150	600	598	329	490	625	275	35	548	245	589
	Sub-Basin Total[10]	6,525	5,100	4,948	6,854	4,465	7,900	3,900	2,811	6,323	5,762	5,538

APPENDIX IIC: (CONT'D.)

South Thompson/ Shuswap Sub-Basin		Stream	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	Avg. 1969-1978
CHINOOK[6]													
AREA 1	(a)	Eagle River	400	300	750	300	400	400	300	250	756	400	425
	(b)	Shuswap River (Lower)	7,500	7,500	7,500	3,500	7,500	10,000	15,000	2,500	9,500	10,400	8,090
		Shuswap River (Middle)	500	750	750	300	400	750	750	400	550	350	550
	(c)	Bessette Creek	N/O	25	25	25	N/O	25	25	N/O	15	20	15
		Area 1 Total[10]	8,400	8,575	9,025	4,175	8,300	11,175	16,075	3,150	10,821	11,170	9,080
AREA 2		Salmon River	200	200	400	200	200	200	200	50	300	350	230
		Area 2 Total[10]	200	200	400	200	200	200	200	50	300	350	230
AREA 3		Seymour River	N/O	N/O	N/O	N/R	N/R	N/R	N/R	N/R	25	N/O	5
		Area 3 Total[10]	--	--	--	--	--	--	--	--	25	--	5
AREA 4		Lower Adams River	5,000	1,500	750	1,500	1,500	1,500	1,500	400	1,750	2,200	1,760
		Area 4 Total[10]	5,000	1,500	750	1,500	1,500	1,500	1,500	400	1,750	2,200	1,760
AREA 5		Little River	200	750	200	100	200	300	400	100	600	100	300
		South Thompson River	7,500	7,500	3,500	5,000	5,000	3,500	7,500	1,500	7,000	3,500	5,150
		Area 5 Total[10]	7,700	8,250	3,700	5,100	5,200	3,800	7,900	1,600	7,600	4,600	5,450
		Sub-Basin Total[10]	21,325	18,525	13,875	10,975	15,200	16,675	25,675	5,200	20,496	18,320	16,525
PINK[7,8]													
AREA 4		Lower Adams River	25	0	25	0	25	0	25	0	1,000	0	115
AREA 5		Little River	25	0	25	0	25	0	N/O	0	2,100	0	220
		South Thompson River	25	0	25	0	25	0	25	0	1,000	0	110
		Sub-Basin Total[10]	75	0	75	0	75	0	50	0	4,100	0	445

APPENDIX IIC: (CONT'D.)

South Thompson/ Shuswap Sub-Basin	Stream	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	Avg. 1969-1978
SOCKEYE[5]												
AREA 1	(a) Eagle River	N/O	33	N/O	N/O	N/O	263	N/O	N/O	N/O	189	48
	(b) Shuswap River (Lower)	1,703	29,074	6,117	N/O	7,452	86,396	11,652	N/O	14,695	187,167	34,426
	Shuswap River (Middle)	N/O	4,559	N/O	N/O	N/O	3,064	N/O	N/O	N/O	10,890	1,851
	Area 1 Total[10]	1,703	33,656	6,117	--	7,452	89,723	11,652	--	14,695	198,246	36,325
AREA 2	Salmon River	N/R	N/R	N/R	N/R	N/R	25	N/R	N/R	6	434	155
	Area 2 Total[10]	--	--	--	--	--	25	--	--	6	434	153
AREA 3	Shuswap Lake	N/O	N/O	N/O	N/O	N/O	N/O	N/O	N/O	N/O	N/O	(9)
	Seymour River	7,327	11,991	19,028	2,889	2,856	45,189	37,024	8,489	5,911	62,929	20,363
	Anstey River	N/O	196	N/O	N/O	N/O	666	N/O	N/O	N/O	886	175
	Hunakwa Creek	N/O	N/O	N/O	N/O	N/O	N/O	N/O	N/O	N/O	N/O	(9)
	Scotch Creek	3,395	304	N/O	47	6,235	464	N/O	41	13,588	2,056	2,613
	Area 3 Total[10]	10,722	12,491	19,028	2,936	9,091	46,319	37,024	8,530	19,497	65,871	23,151
AREA 4	Lower Adams River	45,908	1,297,990	280,176	5,325	33,312	889,613	148,187	5,813	57,964	1,493,473	425,592
	Momich River	N/O	N/O	N/O	1,983	N/O	N/O	N/O	1,998	N/O	N/O	300
	Upper Adams River	N/O	4	N/O	31	N/O	13	23	40	N/O	N/O	15
	Area 4 Total[10]	45,908	1,297,994	280,176	5,359	33,312	881,626	148,210	7,851	57,964	1,493,473	425,907
AREA 5	Little River	6,813	168,881	2,821	81	6,689	112,112	7,268	175	8,686	91,055	40,458
	South Thompson River	630	5,931	10	N/O	545	16,466	16	N/O	432	9,986	3,202
	Area 5 Total[10]	7,442	174,812	2,831	81	7,234	136,578	7,284	175	9,116	91,041	43,660
	Sub-Basin Misc.	236	50,389	1,169	N/O	N/O	41,882	1,442	N/O	N/O	117,932	21,295
MISC.	Sub-Basin Total[10]	66,011	1,569,432	309,321	8,376	57,089	1,204,128	205,612	15,756	101,002	1,966,463	550,493

P Salmon present but not enumerated (not included in calculation of average).
N/O Stream inspected, but no fish observed (included in calculation of average).
N/R No records available (not included in calculation of average).
(1) 1969-1975 included with Eagle River
(2) 1969-1975 included with Shuswap River (Lower).
(3) 1969-1975 included with Bessette Creek.
(4) 1969-1975 included with Salmon River.
(5) Brown et al. (1979).
(6) Brown et al. (1979).
(7) Pink salmon in the Thompson River system spawn in odd years only.
(8) IPSFC Annual Reports 1969-1978.
(9) Included with Sub-Basin miscellaneous.
(10) Yearly totals do not place values on "P" or "N/R" and may, therefore, underestimate overall escapements. Sub-basin ten-year averages are based on the sum of individual stream ten-year averages.

APPENDIX III

THOMPSON RIVER BASIN SALMON ESCAPEMENTS, 1979-1980

	Coho		Chinook		Pink[3]		Sockeye[3]	
	1979	1980	1979	1980	1979	1980	1979	1980
A. THOMPSON RIVER SUB-BASIN								
Thompson River	-	-	-	-	882207	-	-	-
Bonaparte River	-	-	-	-	1128	-	-	-
Deadman River	30	-	30	250	86	-	-	-
Sub-basin Total:	30	-	30	250	883421	-	-	-
B. NORTH THOMPSON SUB-BASIN								
1. LOWER NORTH THOMPSON								
North Thompson River	125	100	1200	750	835	-	1009	36
Louis Creek	1400	700	20	45	-	-	-	-
Barriere Creek	400	60	15	15	-	-	-	133
East Barriere Creek	120	25	-	-	-	-	-	-
Fennel Creek	600	40	-	-	-	-	15590	8437
Mann Creek	-	20	-	-	-	-	-	-
Dunn Creek	400	210	-	10	-	-	-	-
Joseph Creek	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
McTaggart Creek	40	10	-	-	-	-	-	-
Lemieux Creek[2]	-	180	-	-	-	-	-	-
Area 1 Total:	3085	1345	1235	820	835	-	16579	8606
2. UPPER NORTH THOMPSON								
Brookfield Creek	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Clearwater River	250	100	1500	2500	-	-	18	4
Mahood River	5	-	250	150	-	-	-	-
Reg Christie Creek	2	10	-	-	-	-	-	-
Mad River	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Tumtum Creek	2	4	-	-	-	-	-	-
Finn Creek	15	25	425	600	-	-	-	-
Lion Creek	250	300	-	2	-	-	-	-
Blue River	600	300	15	20	-	-	-	-
Albreda River	200	325	-	-	-	-	-	-
Raft River	120	90	175	200	-	-	1780	5418
Area 2 Total:	1444	1154	2365	3472	-	-	1798	5422
Sub-Basin Total:	4529	2499	3600	4292	835	-	18377	14028

APPENDIX III (cont'd)

THOMPSON RIVER BASIN SALMON ESCAPEMENTS, 1979-1980

		Coho[1]		Chinook[1]		Pink[3]		Sockeye[3]	
		1979	1980	1979	1980	1979	1980	1979	1980
C.	SOUTH THOMPSON/SHUSWAP SUB-BASIN								
Area 1	a Eagle River	2500	1500	300	250	-	-	240	2
	South Pass Creek	60	20	-	-	-	-	4	-
	b Blurton Creek	25	16	-	-	-	-	-	-
	Shuswap River (Lower)	300	350	10000	4000	5	-	10092	81
	Shuswap River (Middle)	500	550	500	500	-	-	582	-
	Wap Creek	400	250	-	-	-	-	-	-
	c Bessette Creek	50	60	50	50	-	-	-	-
	Duteau Creek	300	350	-	-	-	-	-	-
	Creighton Creek	30	10	-	-	-	-	-	-
	Harris Creek	150	70	-	-	-	-	-	-
	Area 1 Total:	4315	3176	10850	4800	5	-	10918	83
Area 2	Canoe Creek	75	60	-	-	-	-	-	-
	Tappen Creek	3	-	-	-	-	-	-	-
	Bolean Creek	50	20	-	-	-	-	-	-
	Salmon river	2000	1300	300	360	-	-	-	-
	Area 2 Total:	2128	1380	300	360	-	-	-	-
Area 3	Shuswap Lake	-	-	-	-	-	-	2140	-
	Seymour River	40	6	10	-	-	-	49407	8390
	Anstey River	-	10	-	-	-	-	59	-
	Hunakwa Creek	75	42	-	-	-	-	410	-
	Scotch Creek	N/R	N/R	-	-	-	-	313	205
	Area 3 Total:	115	58	10	-	-	-	52329	8595
Area 4	Lower Adams River	100	200	1000	350	3951	-	275616	2560
	Sinmax Creek	140	30	-	-	-	-	2	-
	Momich River	150	-	-	-	-	-	-	3345
	Upper Adams River	475	75	-	-	-	-	-	560
	Area 4 Total:	865	305	1000	350	3951	-	275618	6465
Area 5	Little River	-	-	700	400	738	-	10443	32
	South Thompson River	-	-	6000	3000	260	-	144	-
	Area 5 Total:	-	-	6700	3400	998	-	10587	32
	Sub-Basin Total:	7423	4919	18860	8910	4954	-	349452	15175

[1]Scott (pers. comm.)
[2]Lemieux Creek was dry in 1979
[3]IPSFC (Annual Reports). Pink salmon in the Thompson River system spawn only during odd years.
N/R No records available